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Engineers' Imaginaries of "the Public": Content Analysis of Foundational Professional Documents

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Abstract

This paper presents results from a content analysis of foundational engineering documents with respect to characterizations of the relationship between engineering and "the public." Fourteen documents were reviewed, including National Academy of Engineering (NAE) reports, ABET accreditation criteria, disciplinary "Bodies of Knowledge," engineering codes of ethics, and organizational/programmatic brochures of leading entities in Learning Through Service (LTS). These documents were selected as repositories of the engineering profession's identity, vision, ambition, and perceived relationship with society. The purpose of the analysis was to identify manifest and latent messages about the engineering profession's institutionally sanctioned imaginaries of "the public."

Guided by a theoretical framework of social imaginaries, three reviewers used qualitative data analysis to identify prevalent themes in how the engineering profession tends to conceptualize "the public." Ninety-nine codes were developed and were broadly divided into six themes: characterizations of "the public," professional duties related to "the public," relationship between engineers and "the public," societal problems in need of engineering solutions, engineers' "social footprint" over time, and vision or mission statements. The most prevalent theme identified overall characterized engineers as benefitting "the public." That engineers "solve problems," and the importance of building or sustaining engineers' professional image in the eye of "the public," were also commonly discussed. Predominant characterizations of "the public" were as members of "developing" countries (e.g., economically, technologically, in terms of industrial capacity and/or sustainable engagement with the environment) and as "lacking information" (e.g., about engineers or what engineers do).

These results are part of a larger study about engineers' imaginaries of "the public" and how these imaginaries might influence the ways engineers see themselves and approach their work, the problems they attempt to solve, and the diverse publics they aim to serve. By examining dominant messages in these documents, as well as noticing absent messages, we can begin to understand the ideologies that inform the critical but often elusive boundary that engineers raise between their profession and society. As such, our analysis constitutes a first step toward deeper insight into how the engineering profession's identity vis-à-vis "the public" might enhance or weaken engineering practice and, ultimately, how it might support or undermine the profession's aspiration to promote the social good.

Introduction

The notion that engineers address societal problems through technical solutions is foundational to official articulations about the engineering profession.[1] Questions, however, have been raised about how this vision translates into practice. They point to limitations in engineers' training and, by extension, competency in determining and promoting the "social good,"[2] as well as to an increasing number of contemporary cases involving engineers' failure to protect the public's health, safety, and welfare.[3] Integral to the engineering profession's service ideal is a relational dimension that portrays engineers as inextricably connected to society. However, in their day-to-day work, engineers tend to make complex and critical decisions – often with significant societal implications – in a relational vacuum, where publics are imagined rather than engaged with. In other words, engineers' imaginaries of "the public" and concomitant assumptions about their proper role in society may play a bigger and more consequential role in engineering practice than commonly realized.

This paper presents results from a content analysis of foundational engineering documents with respect to characterizations of the relationship between engineering and "the public." Our research is part of a larger study about engineers' imaginaries of "the public" and how these imaginaries might influence the ways engineers see themselves and approach their work, the problems they attempt to solve, and the diverse publics they aim to serve.[3] "The public" is an ambiguous category. As such, it holds promise for insight into how engineers imagine the social order in which they operate as well as their own position in it. Our premise is twofold: that *how* engineers conceive of "the public" likely informs their conceptions of self, professional duty, and professional right, as well as engineering decisions, practices, and products; and that knowing *what* imaginaries of "the public" engineering education fosters is necessary for understanding the ideologies that inform the critical but often elusive boundary that engineers raise between their profession and society. Our ultimate goal is to throw into relief the texture of this boundary: What social order might it promote? What values might it reflect? What interests might it serve? What impact might it have on engineers' work and, by extension, relationship with society? We view our analysis as a first step toward deeper understanding about how the engineering profession's identity vis-à-vis "the public" might enhance or weaken engineering practice and, ultimately, how it might support or undermine the profession's aspiration to promote the social good.

Our use of the term "imaginary" is based on philosopher Charles Taylor's conceptualization.[4] Taylor employs the idea of "social imaginary" to trace the evolution of the contemporary Western world's political organization from religious faith to secularity. He argues that catalytic to this shift was "the growth and entrenchment of a new self-understanding of our social existence, one which gave an unprecedented primacy to the individual."[5] Taylor distinguishes social imaginaries from well-articulated visions of social ideals in that, unlike the latter, the former comprise a pre-theoretical, almost subconscious, collective vision. What seems to be especially potent about social imaginaries is that they define in the most elusive of ways the self within the whole, the self's relationship to others, and the norms of accepted and expected social behavior in the context of a larger moral order. Social imaginaries function as the background, a "largely unstructured and inarticulate understanding of our whole situation" that "can never be adequately expressed in the form of explicit doctrines, because of its very unlimited and indefinite nature."[5] As such, they infuse themselves into everyday forms of expression (e.g., stories, images, day-to-day routines) in ways we rarely notice. And once adopted, they are viewed as natural, the only vision of social life possible.

Drawing further from the work of Jasanoff and Kim,[6] we posited elsewhere that the professional formation of engineers cultivates a certain kind of indefinable background, a making sense of the engineer's identity in the larger social world that functions somewhat like Taylor's social imaginary.[3] This background shapes not only how engineers view their profession, but also how they envision themselves and, in contradistinction, "the public." Postulating that different imaginaries of "the public" reinforce different kinds of professional identity and practice, *we hypothesized that engineering education promotes imaginaries that distance engineers from the publics they serve*. In this process, "the public" becomes a rhetorical, as opposed to an empirical, space that reinforces the engineering profession's service ideal and legitimizes engineers' work as promoting the social good, regardless of how diverse publics articulate their own visions, define their own needs, and envision the role of technological applications in their own lives. In light of psychological research establishing a link between professional distancing from those who might be affected by one's actions, moral disengagement, and unethical decision-making[7, 8, 9, 10] *we [suggested] that this rhetorical space comprises fertile ground for suboptimal professional decisions, unethical conduct, and ultimately public harm*[3].

Methods

Fourteen documents were selected as the data set from which to analyze themes characterizing the engineering profession's officially sanctioned imaginaries of "the public." Each of these documents was assigned to one of four categories. Namely:

1. **Professional society "bodies of knowledge" and vision statements (BOK/Vision)**: This category includes four documents that represent how three major professional societies (i.e., Civil, Mechanical, and Electrical) see engineers' role in society and the type of education needed to ensure future practitioners are equipped to meet that role;
2. **Codes of ethics (COE)**: This category includes three documents that represent professional association codes of ethics (i.e., Civil, Mechanical, and non-discipline-specific). These documents were analyzed to capture guiding moral principles expected to inform engineers' professional conduct;
3. **Profession-wide position statements (Prof-wide Position)**: This category includes four documents authored by the National Academy of Engineering (NAE) and ABET, that are not discipline-specific. These documents were selected as representative of a broader set of visions and standards for the engineering profession at large;
4. "**Learning Through Service" literature and organizational statements (LTS)**: This category includes three documents stemming from the LTS community. These documents were chosen to capture curricular and co-curricular visions associated with engineering service projects, usually focused on humanitarian or community development efforts.[7] In light of the fact that LTS draws from service-learning pedagogical foundations – which originate in social science disciplines – and tend to place engineers in direct contact with non-engineering communities, we wanted to examine whether LTS literature portrays "the public" differently than mainstream engineering texts.

The list of documents, by document type, document name, total number of distinct codes assigned to each document, and density of coding for each document are shown in Table 1. In reporting results, the percent of coverage is used as a metric to discuss density of codes that normalizes for the varying document sizes.

Table 1. Data set for document content analysis

Document Type	**Document Name**	**# of pages reviewed (all single-spaced)**	**# of distinct codes used (out of 99)**	**Density of coding (total # of coded segments and codes assigned to each segment)**
Professional Society Bodies of Knowledge and Vision Statements (BOK/Vision)	American Society of Civil Engineers (ASCE) Body of Knowledge V.2[8]	191	61	1069
	ASCE – The Vision for Civil Engineering in 2025[9]	114	52	627
	American Society of Mechanical Engineers (ASME) – 2028 Vision for Mechanical Engineering[10]	28	59	594
	Institute of Electrical and Electronics Engineers (IEEE) Strategic Plan 2015-2020[11]	2	36	151
Codes of Ethics (COE)	ASCE Code of Ethics[12]	4	22	123
	ASME Code of Ethics[13]	2	18	51
	National Society of Professional Engineers (NSPE) Code of Ethics[14]	2	19	97
Profession-wide Position Statements (Prof-wide Position)	ABET Criteria for Accrediting Engineering Programs[15]	31	22	103
	National Academy of Engineering (NAE) – Changing the Conversation: Messages for Improving Public Understanding of Engineering[16]	165	38	563
	NAE – Educating the Engineer of 2020: Adapting Engineering Education to the New Century[17]	209	65	798
	NAE – The Engineer of 2020: Visions of Engineering in the New Century[18]	119	81	1043
Learning Through Service Literature and Organizational Information (LTS)	Colledge (Ed.) – *Convergence: Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs*[19] – Introduction and Chapters 1 & 2	53	55	499
	Engineers Without Borders (EWB) Strategic Plan 2015-2020[20]	8	51	230
	Engineering Projects in Community Service (EPICS) Program Overview Website[21]	1	12	30

Coding

Three reviewers participated in the coding of these documents, using emergent coding techniques.[22] Each reviewer initially coded the same three documents, a trial process that was used to create our list of codes. Paragraphs and entire bulleted lists were our units of analysis. With the goal of identifying dominant elements of the engineering profession's official discourse about "the public," we started our review looking for the most frequently recurring ideas in passages about social groups other than, or broader than, engineers (e.g., "society," "people," "communities"). Within these passages, we initially searched for a small set of broad themes that we anticipated finding (e.g., characterizations of "the public," descriptions of the relationship between engineers and "the public"). As might be expected, in the process of coding, we encountered additional themes (e.g., societal problems in need of engineering solutions, engineers' "social footprint" over time). At the end of the trial process, we examined our three separate codebooks and worked to combine them into one, by a) reaching consensus on the wording and meaning of each code,[1] and b) eliminating codes we deemed far too specific to one of the three initial documents to justify their inclusion in the codebook.[2] There was no disagreement about whether any of the codes we developed were valid or about whether codes we retained should have been eliminated and vice versa. Once we entered the second phase of coding, which involved re-coding the first three documents and coding the rest of the 11 documents using our codebook, we added a few more codes to our list that we developed inductively from the new documents we reviewed.[3] Our final codebook consisted of a total of 99 codes (Appendix), falling under six broad themes given in Table 2.

In the second phase all documents were coded independently by two reviewers. Inter-rater reliability for each code within each document was assessed using Cohen kappa values. A kappa value higher than 0.6 was considered to indicate acceptable agreement.[23] Codes with a lower kappa value were examined further by two of the reviewers. These reviewers went back and examined all the segments to which the code was assigned. When a segment did not seem like a right fit for the code, the code was removed from the segment, the segment was recorded in a separate document, and then discussed by both reviewers to ensure that code and segment were appropriately decoupled. If the decoupling were deemed inappropriate, the code was re-assigned to the segment. For this third round of coding there were no kappa values because the two reviewers built consensus (kappa would be 1). This three-stage coding process (i.e., development of codebook, coding, and re-coding for codes with kappa value below 0.6) was adopted to build confidence in our analysis.

[1] For example, we agreed that the code "lacking information," under the theme "characterizations of the public," would be used for descriptions of "the public" as not knowing what engineering is or what engineers do. We also agreed that the code "technologically illiterate," also under the theme "characterizations of the public," would be used for descriptions of "the public" as lacking proficiency in technical subjects.

[2] One such example is the code "workers" and three sub-codes under it: "skilled," "taxpaying," "young."

[3] Examples include the code "consumers," under the theme "characterizations of 'the public'" and the code "shape the future," under the theme "engineers' professional duties related to 'the public.'"

Table 2. Broad themes

#	Theme name	Theme explanation	# of codes in theme
1	**Characterizations of “the public”**	Statements that gave “the public” a clear and explicit description (e.g., poor, technologically illiterate)	15
2	**Professional duties related to “the public”**	Statements that named engineers’ specific responsibilities toward “the public” (e.g., solve problems, ensure sustainability)	46
3	**Relationship between engineers and “the public”**	Statements that characterized the interactional dynamic between engineers and “the public” (e.g., benefitting, collaborating with)	10
4	**Societal problems in need of engineering solutions**	Statements naming specific social conditions that call for engineering interventions (e.g., natural resource stresses, public health)	24
5	**Engineers’ “social footprint” over time**	Statements characterizing the engineers’ impact on society over time (e.g., consistent, increasing)	3
6	**Vision or mission statements**	Statements spelling out a vision or mission statement for engineering	1
	Total # of codes		99

Results

Our analysis here focuses on the ten most prevalent codes in each of the six themes. For themes with fewer than ten codes (i.e., “engineers’ ‘social footprint’ overtime,” “vision or mission statements”) we analyzed every code in the theme. For each theme, we list the most prevalent codes, offer a brief description of each code, and provide each code’s frequency count – that is, the number of documents that contain the code, the total number of coded segments (paragraphs) with that code assigned to them, and the range of kappa values across documents from the second phase of coding. Finally, we provide the distribution of the codes across the four document categories (i.e., BOK/Vision, COE, Prof-wide Position, LTS) – that is, the number of documents in each category that were assigned the code, and the average “percentage of coverage” of these documents with that code[4] (Tables 3-13).

a. Characterizations of “the public”

In our coding, we used “the public” as an umbrella concept to include any group outside engineering, including scientists and professionals in non-engineering fields. Common references to “the public” were terms like “developing countries,” “communities,” “citizens,” and “society.” The top ten, in order of prevalence, most common codes for this theme are provided in Table 3.

[4] The “percentage of coverage” of any given code is the percentage of a document coded with this code. For example, in our analysis, the code “natural resource stresses” under the theme “societal problems/issues in need of engineering solutions” was assigned to 0.36% of the total text in *Civil Engineering Body of Knowledge for the 21st* Century,[12] 5.89% of the total text in *2028 Vision for Mechanical Engineering*,[14] and 3.69% of the total text in *The Engineer of* 2020.[22] We arrived at the average “percentage of coverage” value for each code by calculating the average of all the percentages of coverage for this code in the documents in which it appeared.

Table 3. Top ten codes related to characterizations of "the public"

#	Code	Description	Frequency count	# of coded segments	Range of kappa values
1	**Developing**	Generally referring to “developing” countries or communities juxtaposed with “developed” countries or communities	4	23	0.5-0.8
2	**Lacking information**	Usually with respect to “the public’s” lack of awareness or understanding of engineering or what engineers do	3	23	0.5
3	**Poor**	Typically referring to “low-income” groups or addressing “the needs of the poor”	7	17	0.5-1.0
4	**Technologically illiterate**	Naming “the public” as unknowledgeable with respect to technology, specifically using the phrase “technologically illiterate”	3	17	0.78-0.86
5	**Lacking/desiring technologies**	Referring to comments about “the public” either lacking technology or desiring technology	5	15	0.5-0.84
6	**Unable to meet basic needs/improve quality of life**	Referring to statements about “the public” as being unable to meet basic needs (e.g., water, shelter, food) or as not having the resources needed to improve their own quality of life	3	13	0.5
7	**Underserved**	Referring to adjectives such as “underserved”, “marginalized” or “underrepresented” to characterize a portion of “the public”	4	9	0.5
8	**Trusting of engineering profession**	Characterizing “the public” as “trusting” of engineers or engineering work to improve the quality of their lives, or that the profession is “entrusted” with certain responsibilities or tasks such as “to create a sustainable world and enhance the quality of life”	2	9	0.5-1.0
9	**Customers**	Identifying “the public” (or portion thereof) as “customers” or potential “customers” of engineering products	3	8	0.5-1.0
10	**Engaged**	Characterizing “the public” as being a part of the engineering process or able to be active with respect to an element of the engineering process. Examples include identifying “the public” as “enlightened citizens” or discussing the need for collaborative or reciprocal relationships between engineers and communities	4	7	0.5-1.0

The distribution of codes across the four document categories and the average percent coverage for each category are shown in Table 4. We emphasize that the average percent coverage reported is averaged only for documents that had at least one instance of the code, and is a way of viewing the results that normalizes for the varying document sizes.

Table 4. Distribution of characterizations of "the public" codes by document category

#	Code	BOK/Vision		COE		Prof-wide Position		LTS	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Developing**	1 of 4	0.58%	0 of 3		1 of 4	1.87%	2 of 3	1.61%
2	**Lacking Information**	1 of 4	0.14%	0 of 3		3 of 4	0.74%	0 of 3	
3	**Poor**	2 of 4	0.36%	0 of 3		3 of 4	0.16%	2 of 3	1.48%
4	**Technologically Illiterate**	0 of 4		0 of 3		3 of 4	0.62%	0 of 3	
5	**Lacking/Desiring Technology**	1 of 4	0.36%	0 of 3		2 of 4	0.52%	2 of 3	1.30%
6	**Unable to meet basic needs/improve quality of life**	0 of 4		0 of 3		0 of 4		2 of 3	3.22%
7	**Underserved**	1 of 4	0.36%	0 of 3		1 of 4	0.14%	2 of 3	1.73%
8	**Trusting of engineering profession**	2 of 4	0.47%	0 of 3		0 of 4		0 of 3	
9	**Customers**	1 of 4	0.58%	0 of 3		1 of 4	0.29%	1 of 3	0.35%
10	**Engaged**	2 of 4	0.20%	0 of 3		1 of 4	0.29%	1 of 3	0.91%

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

Focusing on the five most prevalent characterizations of "the public" (highlighted in Table 4) it is worth noting the following:

i. "The public" as "developing" came primarily from LTS documents, but had a larger average coverage in one non-discipline-specific, profession-wide position statement (*The Engineer of 2020)*. Examples of excerpts with this code include, *"Objectives: Promote understanding of the practices that bring a successful engineering project to fruition in developing communities;*"[24] and "*Helping these countries develop sustainably is not just a challenge for them, but a challenge for the world and for mechanical engineering as a profession.*"[14]

ii. "The public" as "lacking information" about engineering and what engineers do, came primarily from Profession-wide Position Statements. Examples include, "*By 2020, we aspire to a public that will understand and appreciate the profound impact of the influence of the engineering profession on sociocultural systems, the full spectrum of career opportunities accessible through an engineering education, and the value of an engineering education to engineers working successfully in nonengineering jobs;*"[12] and "*Despite these efforts, the impact of engineering on our daily lives, the nature of what engineers do, and the opportunities available through an engineering education are still largely unknown to most Americans;*"[20] "lacking information" as a characterization of "the public" was entirely absent from LTS documents.

iii. "The public" as "poor" (and "underserved") came primarily from LTS documents. Example excerpts with this code include, "*ASCE works in collaboration with other domestic and international organizations to engage engineers in addressing the needs of the poor through capacity building and the development of sustainable and appropriate* *solutions to poverty*;"[12] and "*At the same time, there exists a persistent and growing need to address problems confronting a huge proportion of humanity - those at the Bottom of the Pyramid (BOP). This phrase, BOP, refers to the 2.5 billion people who live on less than $2.50 per day…*"[23]

iv. "The public" as "technologically illiterate" came solely from Profession-wide Position Statements. Example excerpts with this code include, "*Effective messaging can help raise the level of technological literacy in the general population, a key competency for the 21st century*;"[20] and "*The American public is generally quite eager to adopt new technology but, ironically, is woefully technology illiterate and unprepared to participate in discussions of the potential dangers of new technologies or discussions of the value of the national investment in research and development*."[22]

v. "The public" as "lacking/desiring technology" came primarily from LTS documents. Example excerpts include, "*By 2015, and for the first time in history, the majority of people, mostly poor […], will reside in urban centers, mostly in countries that lack the economic, social, and physical infrastructures to support a burgeoning population*;"[22] "*Many underserved communities lack basic infrastructure, depriving them of the ability to improve their quality of life*;"[24] "*Although some research has been done on a number of appropriate technologies, the diffusion of these innovations has greatly lagged the demand in the developing world*.;"[23] and "*Demand for new technologies will sustain global demand for adequately skilled and innovative mechanical engineers in 2028*."[14]

It is noteworthy that although characterizations of "the public" as "unable to meet basic needs/improve quality of life" were only present in LTS documents, they appeared in two of the three LTS documents and had the highest average coverage (at 3.22%) of any other code in this category. It is also important to highlight that characterizations of "the public" as "engaged" were the least prevalent among the top ten codes, and came primarily from LTS documents. Finally, none of the top ten codes characterizing "the public" were present in any of the Codes of Ethics documents.

b. Professional duties related to "the public"

Codes relating to engineers' professional duties with respect to "the public" were assigned to segments in the documents that talked about what action engineers take, or should take, where some segment of the public might be impacted or be the direct recipient of the action. This theme includes codes that are "public-centered," in that they place "the public" in the position of subject who "receives" from engineers, and "engineer-centered," in that they place engineers in the position of subject who must acquire training or skillsets to better serve and/or interact with "the public." The ten most prevalent codes in this theme are provided in Table 5.

Table 5. Top ten codes related to the professional duties of engineers related to "the public"

#	Code	Description	Frequency count	# of coded segments	Range of kappa values
1	**Solve problems**	Referring directly to engineers as “problem solvers” or discussing engineers’ duty as helping to meet pressing societal needs (e.g., infrastructure, sustainability)	11	283	0.52-1.0
2	**Build/sustain professional image**	Discussing the responsibility of engineers to maintain or promote a positive public image of the engineering profession and its practitioners	12	242	0.5-0.9
3	**Ensure sustainability**	Referring to sustainability (generally or in the context of environmental sustainability) and to engineers as playing a key role in the development of “sustainable solutions”	12	201	0.7-1.0
4	**Offer broader training to engineers**	Discussing the need (currently or in the future) for engineers to receive training that goes beyond the “technical” (generally and sometimes with specifics), in order to gain competence in serving or interacting with “the public”	10	161	0.48-0.86
5	**Increase public understanding**	Identifying a responsibility among engineers to raise public awareness or increase public understanding of engineering or what engineers do	11	167	0-0.85
6	**Innovate**	Identifying “innovativeness” or “creativity” as central attributes of engineers, if they are to solve societal problems effectively	8	149	0.49-0.88
7	**Communicate/ interact**	Referring to the need for engineers to communicate effectively or interact with “the public” or to have good communication skills more broadly	9	133	0.5-1.0
8	**Better prepare students**	Referring to the need for engineering students to be better prepared to address current or future societal problems	10	132	0.49-0.80
9	**Enter public sphere/public policy**	Referring to engineers’ responsibility to inform or contribute to public policy development, generally around the use of technology, or to become more involved in the public sphere/public policy arenas	9	131	0-0.96
10	**Develop/support leaders in engineering**	Discussing the need to develop or support leaders within the engineering community who can fulfill competently their duty as societal stewards of technical expertise	9	119	0.49-0.87

The distribution of codes across the four document categories and the average percent coverage for each category are shown in Table 6.

Table 6. Distribution of professional duties related to "the public" codes by document category

#	Code	BOK/Vision		COE		Prof-wide Position		LTS	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Solve Problems**	4 of 4	2.84%	0 of 3		4 of 4	3.65%	3 of 3	7.98%
2	**Build/Sustain Professional Image**	4 of 4	6.10%	3 of 3	8.42%	4 of 4	3.35%	1 of 3	6.26%
3	**Ensure Sustainability**	3 of 4	3.49%	3 of 3	4.57%	4 of 4	1.08%	2 of 3	6.61%
4	**Offer Broader Training to Engineers**	4 of 4	1.32%	2 of 3	3.16%	3 of 4	3.35%	2 of 3	1.72%
5	**Increase public understanding**	3 of 4	2.96%	0 of 3		4 of 4	2.05%	3 of 3	6.92%
6	**Innovate**	4 of 4	1.92%	0 of 3		3 of 4	2.97%	1 of 3	1.04%
7	**Communicate/ Interact**	3 of 4	1.26%	0 of 3		4 of 4	1.22%	2 of 3	2.67%
8	**Better prepare students**	4 of 4	2.27%	0 of 3		4 of 4	4.19%	2 of 3	5.33%
9	**Enter public sphere/ public policy**	4 of 4	2.35%	2 of 3	3.74%	2 of 4	1.61%	1 of 3	1.13%
10	**Develop/Support Leaders in Engineering**	4 of 4	2.91%	0 of 3		3 of 4	1.02%	2 of 3	5.18%

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

Focusing on the five most prevalent professional duties related to "the public" (highlighted in Table 6), it is worth noting the following:

i. The responsibility of engineers to "solve problems" was a dominant theme in most of the documents, and present in all documents except for the three in the Codes of Ethics category. Example excerpts with this code include, "*Engineering practice often includes aesthetic, ethical, and historical considerations and other elements of the humanities. Therefore, engineers must be able to recognize and incorporate such human elements into the development and evaluation of solutions to engineering and societal problems*;"[12] "*Mechanical engineering will evolve and collaborate as a global profession over the next 20 years through a shared vision to develop engineering solutions that foster a cleaner, healthier, safer and sustainable world*;"[14] and "*EPICS is a unique program in which teams of undergraduates are designing, building, and deploying real systems to solve engineering-based problems for local community service and education organizations*."[25]

ii. The responsibility of engineers to "build/sustain" the engineering profession's public image appeared frequently and consistently in all but two LTS documents. It was especially dominant in the Codes of Ethics documents. Example excerpts with this code include, "*The Summit participants identified the need to create greater public awareness of the essential contributions of engineering to quality of life consistent with a sustainable world*;"[14] and "*Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero-tolerance for bribery, fraud, and corruption*."[16]

iii. Engineers' duty to "ensure sustainability" also appeared in all but two documents, and was most prevalent in the Codes of Ethics and LTS documents. It is clearly a dominant theme in the engineering profession's vision of its role in society. Example excerpts with this code include, "*Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations*;"[18] "*Engineers should endeavor to extend the public knowledge of engineering and sustainable development, and shall not participate in the dissemination of untrue, unfair or exaggerated statements regarding engineering*;"[16] and "*As an engineer, as part of a multidisciplinary team in programs such as the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State for example, students are asked to address such ill-defined problems – and actually implement sustainable solutions!*"[23]

iv. The engineering profession's duty to "offer broader training to engineers" was most prevalent in the Profession-wide Position Statements. Example excerpts with this code include: "*Many of the outcomes outlined in the BOK will require engineers to function horizontally—they will be stretched beyond the comfort of their silos. Fulfilling such outcomes as 3 (humanities), 4 (social sciences), 8 (problem recognition and solving), 10 (sustainability), 11 (contemporary issues and historical perspectives), 12 (risk and uncertainty), 16 (communication), 17 (public policy), 19 (globalization), 21 (teamwork), and 22 (attitudes) will enable you to further develop horizontal thinking*;"[12] and "*Educating future civil engineers is also an essential component of the vision for the civil engineering profession in 2025. Fulfilling the vision requires an expanded set of knowledge, skills, and attitudes, highlighting the need for curricula reform today to develop that knowledge and those skills and attitudes needed in 2025*."[13]

v. Engineers' duty to "increase public understanding" of engineering or what engineers do appeared in all four Profession-wide Position Statements, three of the four BOK/Vision documents, and all three LTS documents. Further, all these documents featured statements revealing a conviction that "the public" has little understanding of what engineers do, and often fails to recognize the significant impact of engineering work on people's daily lives. They presented "increased public understanding" as critical for influencing public decisions and recruiting future engineers. *Changing the Conversation*, by the NAE, is probably the most focused document on this subject. Example excerpts with this code include, "*We aspire to a public that will recognize the union of professionalism, technical knowledge, social and historical awareness, and traditions that serve to make engineers competent to address the world's complex and changing challenges*;"[22] "*Mechanical engineers need to make sure the public and policy makers are aware of the capabilities mechanical engineers offer to a sustainable world*;"[14] and "*A better understanding of engineering would educate policy makers and the public as to how engineering contributes to economic development, quality of life, national security, and health*."[20]

c. Relationship between engineers and "the public"

Codes under this theme were assigned to segments in the documents characterizing the relationship between engineers and "the public," both in terms of impact (e.g., benefitting, engaging, harming "the public") and in terms of the impact's directionality (e.g., engineers impacting public policy; “the public” impacting engineers). All ten codes under this theme are presented in order of prevalence in Table 7.

Table 7. Top ten codes related to the relationship between engineers and “the public”

#	Code	Description	Frequency count	# of coded segments	Range of kappa values
1	**Engineers benefitting “the public”**	Referring to general or specific ways in which the work of engineers helps and supports society at large or an identified sub-population, such as a community organization, local school, or group relocating to an urban area. Positive effects of engineering products and interventions were often characterized as “significantly improving” existing conditions, “mitigating” negative effects, and “providing solutions”	12	346	0.5-0.85
2	**“The public” impacting engineers**	Discussing instances where an action, trend, expectation, or information from “the public” has an impact on engineers (e.g., how they prepare to address a problem, how they develop student recruitment strategies, how they think about engineering education)	9	192	0.49-0.83
3	**Cross-disciplinary/ interdisciplinary/ interdependent**	Referring to instances where the relationship between engineers and “the public” or simply a group outside engineering is characterized as “cross-disciplinary,” “interdisciplinary,” or “interdependent”	11	154	0.45-0.83
4	**Collaborative**	Characterizing the relationship between engineers and “the public” as one that involves some form of collaboration through, for example, partnerships. This code was also assigned to calls for collaborative relationships with “the public”	11	123	0-0.72
5	**Engineers engaging “the public”**	Referring to discussions about engineers interacting, communicating, or engaging in some form with “the public,” without however specific mention of the public interacting or contributing back	9	40	0.5-0.71
6	**Engineers impacting public policy**	Referring to discussions about the need for or ability of engineers to contribute to public policy decision-making or development	7	37	0-0.83
7	**Engineers impacting non-engineering professionals**	Characterizing references to the impact of engineers or engineering decisions on non-engineering professionals, as opposed to the general public or society	4	16	0.5-1.0
8	**Engineers harming “the public”**	Referring to instances where engineers or the result of engineering work has harmed or has the potential to harm “the public”	4	6	0.5-0.7

9	**Justification for the relationship**	Characterizing statements defending the need for or importance of a relationship between engineers and "the public"	2	6	0.5
10	**Relationship is not…**	Characterizing statements identifying what the relationship between engineers and "the public" is not (e.g., "engineering will not operate in a vacuum separate from society")	4	5	0-0.5

The distribution of codes across the four document categories and the average percent coverage for each are shown in Table 8.

Table 8. Distribution of codes defining the relationship between engineers and "the public" by document category

#	Code	BOK/Vision		COE		Prof-wide Position		LTS	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Engineers benefitting "the public"**	4 of 4	8.92%	3 of 3	7.89%	3 of 4	5.24%	3 of 3	20.30%
2	**The public impacting engineers**	3 of 4	1.78%	0 of 3		3 of 4	4.33%	3 of 3	8.44%
3	**Cross-disciplinary/ interdisciplinary/ interdependent**	4 of 4	2.93%	0 of 3		4 of 4	1.68%	3 of 3	9.70%
4	**Collaborative**	4 of 4	4.48%	0 of 3		4 of 4	0.77%	3 of 3	13.61%
5	**Engineers engaging "the public"**	4 of 4	1.78%	1 of 3	1.09%	3 of 4	0.46%	1 of 3	2.16%
6	**Engineers impacting public policy**	4 of 4	1.70%	0 of 3		2 of 4	0.76%	1 of 3	0.48%
7	**Engineers impacting non-engineering professionals**	2 of 4	4.56%	0 of 3		1 of 4	0.37%	1 of 3	11.79%
8	**Engineers harming "the public"**	2 of 4	0.13%	0 of 3		2 of 4	0.18%	0 of 3	
9	**Justification for the relationship**	0 of 4		0 of 3		2 of 4	0.45%	0 of 3	
10	**Relationship is not…**	0 of 4		1 of 3	2.06%	3 of 4	0.09%	0 of 3	

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

Focusing on the five most prevalent codes characterizing the relationship between engineers and "the public" (highlighted in Table 8), we note the following:

i. The code "engineers benefitting the public" was the most prevalent in this theme, appearing in all but one documents (the ABET accreditation guidelines), with an overall average coverage of 10.58%. Examples of segments with this code include, "*Engineers make a world of difference. From new farming equipment and safer drinking water to electric cars and faster microchips, engineers use their knowledge to improve people's lives in meaningful ways;*"[20] "*Several aspects of the vision relate to the civil engineer's interaction with the public. Civil engineers aim to be—and be perceived as—trusted advisors to the public and policy-makers regarding infrastructure. To accomplish this, civil engineers must show the public how their services touch the public daily and improve lives.*

In particular, the civil engineering community must increasingly seek opportunities to use its abilities to improve the quality of life in more areas of the world with our services;"[13] and "*Mechanical engineers can be at the forefront of developing new technology for environmental remediation, farming and food production, housing, transportation, safety, security, healthcare and water resources. In doing so, engineers can create sustainable solutions that meet the basic needs and improve quality of life for all people around the world*."[14]

ii. The code "'the public' impacting engineers" appeared especially prominently in the LTS documents although it was prevalent in the Profession-wide Position Statements as well. Examples of segments with this code include: "*The external forces in society, the economy, and the professional environment will all challenge the stability of the engineering workforce and affect our ability to attract the most talented individuals to an engineering career*;"[21] "*Civil engineers thus find themselves as keepers of an impressive legacy while raising concerns about future directions. They know they must take more risks. They know they must show more leadership. They know they must control their own destiny rather than letting events control them*;"[13] and "*The public has become increasingly aware that development need not result in a compromised and depleted environment. Enlightened citizens see sustainability, not as an unattainable ideal, but as a practical goal. To answer that call, civil engineers realize that they must increasingly transform themselves from designers and builders to project life-cycle 'sustainers.'*"[13]

iii. Characterizations of the relationship between engineers and "the public" as "cross-disciplinary/interdisciplinary/interdependent" appeared in all documents except for the Codes of Ethics; they were most prevalent in LTS documents, wherein they tended to appear as calls for partnerships with multiple and diverse stakeholders, including both experts in non-engineering fields and community members; examples of segments with this code include: "*However, contemporary challenges—from biomedical devices to complex manufacturing designs to large systems of networked devices—increasingly require a systems perspective. This drives a growing need to pursue collaborations with multidisciplinary teams of technical experts*;"[21] "*Students face a future in which they will need more than just a discipline-specific background to be successful. In setting the goals for any project or task they may be asked to undertake, students will be expected to interact effectively with people of widely varying social, cultural and educational backgrounds. They will then be expected to work with people from many different disciplines to achieve these goals*;"[23] and "*The following list of core values reflects what is truly important to us as an organization: […] Global Community Building: cultivating active, vibrant, and honest exchange among cross-disciplinary and interdisciplinary global communities of technical professionals*."[15]

iv. Similarly, characterizations of the relationship between engineers and "the public" as "collaborative" appeared in all documents except for the Codes of Ethics and were the most prevalent in LTS documents; examples of segments associated with this code also emphasize the centrality and necessity of working as a "team" with multiple and diverse stakeholders; they include the following excerpts: "*A global spirit of collaboration and partnership is essential to achieving the 2028 vision. Mechanical engineering will need to* *embrace partnerships among industry, government and academia to support and expand research and development and recruit and educate the next generation of mechanical engineers;*"[14] "*Objectives: Build collaborative relationships with the larger development and engineering communities: universities, industry professionals, corporations, donors, non-governmental organizations and governmental organizations;*"[24] and "*Although the sections above have shown the clear benefits from an educational perspective for SL [service learning], this does not mean that the assistance engineering students can provide to both local communities [sic] and the global community should be ignored. Service learning provides an ideal vehicle for students to apply their academic skills toward this end through engagement and collaboration with marginalized communities.*"[23]

v. The code "engineers engaging 'the public'" appeared in all document categories and was the most prevalent in one LTS document (*Convergence*); examples of excerpts with this code include: "*Engineers themselves should be central to the reframed image of engineering. They work with people, not abstract fields of study or career pursuits. The message should include humor, wit, and irony to convey a human quality to the tone and voice behind the message. Messages that break through the clutter must make an emotional connection with their audiences, especially a young audience. The message should use their language, not impose our language. Language and word choices have a direct bearing on the emotional appeal of a message;*"[20] and "*Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community.*"[18]

d. Societal problems in need of engineering solutions

Frequently, engineers' role with respect to "the public" was described in the context of specific societal problems requiring engineering expertise for their solution. The ten most prevalent codes in this theme are provided in Table 9.

Table 9. Top ten codes related to societal problems in need of engineering solutions

#	Code	Description	Frequency count	# of coded segments	Range of kappa values
1	**Natural resource stresses**	Referring to scarcity of natural resources, environmental degradation, or the need for sustainable solutions	9	97	0.5-0.87
2	**Physical infrastructure stresses**	Referring to absence or deterioration of built infrastructure necessary for sustaining the global population and quality of life	7	59	0.5-0.81
3	**Quality of life**	Referring to statements that specifically include references to "quality of life" or aspects of daily life in relation to problems that engineers can address	9	55	0-0.66
4	**Population increase**	Referring to global population growth as a problem that needs to be addressed, at least in part, through engineering solutions	7	47	0.5-1.0
5	**Health**	Discussing problems, challenges, or achievements in population-based health	6	42	0.5-0.78

6	**Political instability**	Referring to political instability as a societal challenge that may affect engineers or which engineers may be able to address	5	36	0.5-1.0
7	**Economic infrastructure stresses**	Discussing economic instability and the need for economic growth, "entrepreneurial solutions," or economic sustainability	4	34	0.49-0.7
8	**Unspecified challenges**	Referring to vague statements of general problems or "challenges"	7	32	0.5
9	**Aging society**	Referring to strains on financial systems, healthcare, or employment as a result of increased life expectancy	2	23	0.95
10	**Education**	Referring to the capacity of engineers to facilitate both technical and more general education among specific communities (not educate "the public" about engineering)	3	15	0.5-1.0

The distribution of codes related to societal problems that engineers can address and the average percent coverage for each are shown in Table 10.

Table 10. Distribution of codes by document category referencing societal problems in need of engineering solutions

#	**Code**	**BOK/Vision**		**COE**		**Prof-wide Position**		**LTS**	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Natural Resource Stresses**	3 of 4	2.67%	1 of 3	0.67%	4 of 4	1.18%	1 of 3	1.08%
2	**Physical Infrastructure Stresses**	3 of 4	1.59%	0 of 3		2 of 4	1.70%	2 of 3	0.70%
3	**Quality of Life**	3 of 4	1.92%	2 of 3	2.14%	2 of 4	1.65%	2 of 3	0.83%
4	**Population Increase**	3 of 4	1.35%	0 of 3		3 of 4	0.87%	1 of 3	0.17%
5	**Public Health**	2 of 4	1.80%	0 of 3		2 of 4	1.64%	1 of 3	1.73%
6	**Economic Infrastructure Stresses**	3 of 4	0.44%	0 of 3		2 of 4	1.58%	0 of 3	
7	**Political Instability**	1 of 4	0.99%	0 of 3		2 of 4	1.88%	1 of 3	1.21%
8	**Unspecified Challenges**	2 of 4	1.00%	0 of 3		2 of 4	0.82%	3 of 3	3.06%
9	**Aging Society**	0 of 4		0 of 3		2 of 4	1.06%	0 of 3	
10	**Education**	1 of 4	0.29%	0 of 3		2 of 4	1.05%	0 of 3	

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

Focusing on the five most prevalent codes concerning societal problems in need of engineering solutions (highlighted in Table 10), we note the following:

i. "Natural resource stresses" was the most prevalent code discussed in every document category, but had the greatest average percent coverage in the Professional Society Bodies of Knowledge and Vision Statements. Examples of excerpts with this code include: "*An ever-increasing global population that is shifting even more to urban areas will require widespread adoption of sustainability. Demands for energy, transportation, drinking water, clean air, and safe waste disposal will drive environmental protection and infrastructure development. Society will face threats from natural events, accidents, and perhaps such other causes as terrorism;*"[12] "*Whenever society has needed great contribution from* *mechanical engineering in the past, the profession has stepped up to the challenge. All that will be different in 2028 is the increased scope of the challenges and the increased number of people who will be living in a cleaner, healthier, safer and sustainable world because mechanical engineers believed they should;*"[14] and "*The program must prepare graduates to have: […] engineering knowledge to design solutions to geological engineering problems, which will include one or more of the following considerations: the distribution of physical and chemical properties of earth materials, including surface water, ground water (hydrogeology), and fluid hydrocarbons; the effects of surface and near-surface natural processes; the impacts of construction projects; the impacts of exploration, development, and extraction of natural resources, and consequent remediation; disposal of wastes; and other activities of society on these materials and processes, as appropriate to the program objectives*."[19]

ii. The code "physical infrastructure stresses" was discussed in three of the four document categories, not in the Codes of Ethics. It had the greatest average percent coverage in the Profession-wide Position Statements. Examples of excerpts with this code include: "*The ecosystem is complex and its tipping points are not well understood. We do not know how much time we have to create the solutions that ensure sustainability. Global resources, related to energy and water, are already stressed and likely to be more so as the population grows to more than eight billion people. The requirements for infrastructure and social programs for this growing global population will be great*;"[14] and "*Although the United States has arguably had the best physical infrastructure in the developed world, the concern is that these infrastructures are in serious decline. Because it is of more recent vintage, the nation's information and telecommunications infrastructure has not suffered nearly as much degradation, but vulnerabilities of the infrastructure (or infrastructures) due to accidental or intentional events are well recognized and a serious concern*."[21]

iii. The code "quality of life" appeared in all four document categories but had the greatest average percent coverage in the Codes of Ethics category. Examples of excerpts with this code include: "*Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare*;"[18] "*Engineers have a long track record of addressing the needs of people. From the design and construction of bridges which facilitate the transport of food stuffs to market, to developing life-saving pharmaceuticals, to development of electrical devices which lighten life's burdens, and on and on. Engineering, as a discipline, has improved the lives of many billions of people around the world over time*;"[23] and "*Informed by this state of the civil engineering profession and the challenges and opportunities facing it, the aspirational global vision developed as a result of the Summit is: Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master*…"[13]

iv. The code "population increase" appeared in all document categories except for the Code of Ethics. Examples of excerpts with this code include: "*Globally there is a huge market for mechanical engineering that serves the poorest among us. Currently, it is estimated that around four billion people live on less than $2 per day. By 2030, almost two billion* *additional people are expected to populate the earth, ninety-five percent of them in developing or underdeveloped countries. This large and growing population will need access to food and clean water, effective sanitation, energy, education, healthcare and affordable transportation;*"[14] and "*Engineering could not be more relevant. Our society is becoming increasingly complex. We must provide more food and energy for a rapidly growing population, and we must limit damage to the environment in the process. Engineering will play a big role in meeting these challenges*."[20]

v. Problems, challenges, or achievements in population-based health were discussed in all document categories except for the Codes of Ethics. Examples of excerpts with the code "health" include: "*Engineering, through its role in the creation and implementation of technology, has been a key force in the improvement of our economic well-being, health, and quality of life. Three hundred years ago the average life span was 37 years, the primary effort of the majority of humans was focused on provisioning their tables, and the threat of sudden demise due to disease was a lurking reality. Today, human life expectancy is approaching 80 years in many parts of the world as fundamental advances in medicine and technology have greatly suppressed the occurrence of and mortality rates for previously fatal diseases and the efforts of humankind are focused largely on enhanced quality of life;*"[22] and "*The present global picture is sobering and demonstrates how far we are from a just, sustainable world: Around 1.2 billion people live on less than $1 a day and 2.8 billion people live on less than $2 a day. Ingestion of unsafe water, inadequate availability of water for hygiene, and lack of access to sanitation contribute to about 1.5 million child deaths and around 88% of deaths from diarrhea every year. Overall 10.8 million children under the age of five die each year from preventable causes – equivalent to about 30,000/day*."[23]

e. Engineers' "social footprint" over time

Based on our first round of coding, during which we noticed several statements about engineers' increasing impact on society, we developed three a priori codes concerning engineers' "social footprint" on society over time, in order to capture any trends in the engineering profession's sense of its involvement with, or effect on, "the public." The three codes characterize engineers' "social footprint" as "increasing," "consistent," and "decreasing." Their frequency in the documents is shown in Table 11. With only one exception, all excerpts discussing engineers' social impact over time characterized the impact as "increasing" (both historically and in terms of projections into the future). The single reference that did not, characterized the impact as "consistent" (this was a historical reference). We encountered no references to engineers' social footprint decreasing over time.

Table 11. Frequency and initial inter-rater reliability for all codes for characterizations of the social footprint of engineers over time

#	Code	# of documents with code	# of coded segments	kappa values from 2nd round
1	**Social footprint increasing**	7	70	0.50 – 0.84
2	**Social footprint consistent**	1	1	0.50 - 1.0
3	**Social footprint decreasing**	0	0	

The distribution of codes characterizing engineers' social footprint over time across the four document categories and the average percent coverage for each category are shown in Table 12.

Table 12. Distribution of codes by document type pertaining to engineers' social footprint over time

#	Code	BOK/Vision		COE		Prof-wide Position		LTS	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Social footprint increasing**	3 of 4	0.36%	0 of 3		2 of 4	3.12%	2 of 3	8.89%
2	**Social footprint consistent**	0 of 4		0 of 3		1 of 4	0.08%	0 of 3	
3	**Social footprint decreasing**	0 of 4		0 of 3		0 of 4		0 of 3	

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

This set of findings suggests that the engineering profession sees its role in society as increasing. Statements making this claim seemed to be driven largely by the increasing complexity of the world in terms of globalization, growing population, environmental, physical, and social stresses as well as the desire for new technologies by "the public." Examples of excerpts with this code include: "*Several of the cited NAE needs and goals align naturally with the future preparation of civil engineers: […]The convergence between engineering and public policy will increase as technology becomes more permanently engrained into society*;"[12] "*With technology becoming ever more pervasive in society, it is incumbent on the engineering profession to lead in shaping the ultimate use of technology and the government processes that control, regulate, or encourage its use*;"[22] "*This strategic plan highlights three complementary goals where EWB-USA will focus our efforts to support sustainable growth that is beneficial to all of our stakeholders. As we take tangible steps to achieve this plan, EWB-USA will strengthen and grow -- and so will our impact*."[24]

f. Vision or mission statements

For this theme, we coded excerpts as "vision or mission statement" if they articulated explicitly a particular vision or mission for the engineering profession or engineering organization. Our purpose was to capture any broader "ideal" or "ideals" that the engineering profession sees itself as embracing (or seeking to embrace). This code was assigned to 63 segments in 8 documents. Its distribution across the four document categories as well as the average percent coverage for each category are shown in Table 13.

Table 13. Distribution of codes by document category pertaining to vision or mission statements

#	Code	BOK/Vision		COE		Prof-wide Position		LTS	
		# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover	# with code	Avg. % Cover
1	**Vision or mission statement**	4 of 4	1.87%	0 of 3		3 of 4	0.47%	1 of 3	12.38%

BOK/Vision = Professional Society Bodies of Knowledge and Vision Statements; COE = Codes of Ethics; Prof-wide Position = Profession-wide Position Statements; LTS = Learning Through Service Literature and Organizational Information

Not surprisingly, the code "vision or mission statement" appeared in all Professional Society Bodies of Knowledge and Vision Statements. It also appeared in three of four Profession-wide Position Statements. Although it appeared in only one LTS document (*Engineers Without*

Borders), it had by far the largest percent coverage in this document at 12.38%. Excerpts with this code tend to articulate an aspiration to a public that "entrusts" well-rounded and innovative engineers to be the technological stewards of 21st century advancement by doing one or more of the following: a) enhancing quality of life through engineering solutions to 21st century challenges (e.g., population increase, infrastructure needs, natural resource stresses); b) disseminating expertise, new technologies, and services to all, including the most economically disadvantaged; c) taking a leadership role in influencing political decision-making and public policy on issues related to science, engineering, and technology; and d) informing and collaborating with government, industry, and academia as well as with non-engineering disciplines such as science, social science, and business. Coupled with this ideal seems to be a vision of a shifting relationship between engineers and "the public" whereby the latter achieves increased understanding about engineers' contributions to society and, as a consequence, increased appreciation for the engineering profession overall. A concomitant outcome is a stronger "union" of engineers and "the public" through increased student enrollment in engineering education programs – especially of diverse and underrepresented populations – as well as improvement on the part of engineers to "recruit, nurture, and welcome" such groups.[22] Examples of excerpts with this code include:

"*No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people's everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century*;"[20] "*We will be essential to the global technical community and to technical professionals everywhere, and be universally recognized for the contributions of technology and of technical professionals in improving global conditions*;"[15] "*EWB-USA builds a better world through engineering projects that empower communities to meet their basic human needs and equip leaders to solve the world's most pressing challenges*;"[24] and "*We aspire to a public that will recognize the union of professionalism, technical knowledge, social and historical awareness, and traditions that serve to make engineers competent to address the world's complex and changing challenges*."[12]

Discussion

Our content analysis of 14 foundational engineering documents highlights six prevalent themes in engineers' imaginaries of "the public": characterizations of "the public;" professional duties related to "the public;" relationship between engineers and "the public;" societal problems in need of engineering solutions; engineers' "social footprint" over time; and vision or mission statements related to "the public." An examination of codes under these themes reveals the following:

The most prevalent characterizations of "the public" emphasize sub-optimal living conditions (i.e., being poor, "developing," lacking basic technologies and infrastructure) and informational deficiencies (i.e., lacking knowledge about engineering and the risks and benefits of technologies). But they also portray "the public" as desirous of engineering innovations. Characterizations of "the public" as "engaged" – that is, as being part of the engineering process or having the capacity to be active with respect to the engineering process – were the least prevalent among the top ten codes and came primarily from LTS documents. Finally, none of the top ten codes under the theme "characterizations of 'the public'" were present in Codes of Ethics. Although all three Codes of Ethics documents render "the public's" safety, health and welfare as engineers' foremost responsibility, they leave "the public" as an amorphous category, distinct primarily through its differentiation from engineers' "clients" and "employers."

"Solving problems" and "building/sustaining the profession's image" were the most commonly mentioned duties related to "the public." This combination of, what seem to be, a "public-centered" and an "engineer-centered" set of duties signals the mixed focus of the codes that follow. The third most prevalent duty – "ensure sustainability" – suggests an outward looking engineering profession that places "the public," the environment, and the survival of people and the planet at the center. The remaining duties, however, involve responsibilities toward the engineering profession, its students, and its practitioners that are *related* to "the public," and can certainly be important for effective engineering interventions, but are not defined consistently and unequivocally as aiming to directly benefit "the public" (i.e., "offer broader training to engineers," "increase public understanding," "innovate," "communicate/interact," "better prepare students," "enter public sphere/public policy," "develop/support leaders in engineering"). In fact, references to these duties often highlight that their fulfillment can elevate the engineering profession in the eyes of "the public" and propel engineers' professional achievement, career options and success, as well as ability to influence the views of others.

The most prevalent code, by far, among all codes falls under the theme "relationship between engineers and 'the public.'" It is that engineers "benefit 'the public.'" Passages assigned to this code tend to depict engineers as leaders in a) creating a sustainable world that meets the needs of all people; b) enhancing the global quality of life; c) improving and protecting the environment; d) meeting challenges in multiple areas, including energy, food, water, housing, transportation, and infrastructure; and e) generally making the world "a better place."[23] Notably, the second most prevalent code under the same theme suggests that the flow of influence between engineers and "the public" is perceived as bidirectional: engineers may impact "the public," but "the public" impacts engineers as well. Passages under this code tend to portray "the public" as a multi-dimensional entity that can take the form of a) employers who can have a significant influence over engineers' careers; b) professionals in non-engineering fields who can enhance engineers' ability to identify and solve societal problems; c) future engineering students who can have diverse identities, interests, sensibilities, cultural backgrounds, and learning styles and, therefore, can require different messaging from the engineering profession for effective recruitment; d) community organizations and community partners in the US and abroad that can offer engineers practice in communication, leadership, and teamwork skills in exchange for engineers' service; e) individual consumers, as well as small and large groups, who can have needs and desires for specific engineering solutions, and can be catalytic in the development of new technologies; and finally, f) social, economic, and political forces – such as globalization, industry demands, market trends, changing demographics, economic trends, public policies, public perceptions of engineering, the shifting landscape in information sharing and crowdsourcing, funding mechanisms, and terrorism risks – that can affect and sometimes even dictate the thinking, practices, boundaries, and future direction of the profession.

Against this backdrop, perhaps it is not surprising that the third and fourth most prevalent characterizations of the relationship between engineers and “the public” were “cross-disciplinary/interdisciplinary/interdependent” and “collaborative.” These characterizations were used primarily in reference to engineers who a) work in settings that are, by nature, interdisciplinary (e.g., government, industry, academia); b) are members of diverse, multicultural, and/or interdisciplinary project teams and, as a result, are expected to be able to encourage and integrate multiple perspectives and think in “non-traditional ways;”[21] c) are engaged in complex projects requiring not only engineering but also non-engineering knowledge and are, therefore, expected to act as “master integrators”[12] of different types of information; d) seek to expand research and product development and are, therefore, expected to foster partnerships between multiple sectors (e.g., government, industry, and academia); e) seek to inform public policy and are, therefore, expected to communicate effectively with non-engineering professionals and policymakers; f) seek to foster in students strong leadership and communication skills, applied research and entrepreneurial skills, ability to operate successfully in non-engineering settings, cross-cultural awareness, competences likely to be sought in future global markets, and/or confidence in their capacity to enrich their field by generating knowledge from new perspectives and are, therefore, expected to create opportunities for student participation in interdisciplinary teams; and/or g) seek to shift the focus of engineering education from “course instruction” to “multi-disciplinary collaborations” or seek to incorporate LTS programs into existing engineering education curricula and are, therefore, expected to establish partnerships with non-engineering departments and institutions.

Passages assigned to the code “engineers engaging ‘the public’” – the fifth most prevalent characterization of the relationship between engineers and “the public” – reveal an interest within the engineering profession in seeing engineers involve themselves in conversations, initiatives, and events outside the workplace that can benefit from engineering expertise (e.g., zoning commissions, environmental and infrastructure policy negotiations, capital improvement committees, schools, youth organizations). They stress that this type of engagement can support non-engineering publics to make technically informed decisions and can even propel such publics into action. At the same time, they point out that engineers’ engagement with “the public” holds promise for familiarizing engineers with “the public’s” concerns; strengthening engineers’ partnership with diverse stakeholders; sharpening their cross-disciplinary communication skills; offering them feedback that could prove useful in the creation of new technologies; introducing engineering knowledge, contributions, and visions in diverse cultures and settings; increasing “the public’s” trust of engineers; and ultimately elevating the quality of engineering innovations and interventions. One of the LTS documents also asserts that engineers’ engagement with “the public” holds promise for enabling communities to articulate their own needs, goals, and visions, and for seeing their knowledge, skills, and culture be “respected.”[23]

When it comes to societal problems most in need of engineering solutions, the foundational engineering documents we analyzed seem to focus on a set of interrelated challenges: natural resource stresses (due, in large part, to increasing demand for diminishing resources); physical infrastructure stresses (due, in large part, to aging or non-existent infrastructure); sub-optimal quality of life (due, in large part, to increasing global poverty); global population increases; and sub-optimal public health, especially among the poor. These significant and complex problems, combined with a perceived sense of a growing public appetite for new technologies, leads engineers to the conclusion that their role in society is only going to increase. Hand-in-hand with this belief is an aspiration that "the public" will "entrust" engineers to serve as 21st century technological stewards and will embrace engineering as a field that is important and inspiring and, by extension, worth joining, supporting, strengthening, and expanding.

Conclusion

In this study, we set off to examine engineers' imaginaries of "the public" as reflected in foundational engineering documents. Postulating that different imaginaries reinforce different kinds of professional identity and practice, we hypothesized that engineering education promotes imaginaries that distance engineers from the publics they serve. We also anticipated that LTS literature would portray "the public" differently from more mainstream engineering texts. The mere number of documents we reviewed (14), size of our codebook (99 codes), and total number of excerpts we coded (4,679), allow for multiple layers of analysis that go beyond the scope of this paper. However, a close look at the most prevalent codes under each of the six themes provides initial insights about how the engineering profession positions itself in relation to "the public," societal problems, and engineering solutions.

At the center of engineers' imaginaries of "the public" lies an aspiration and conviction that engineers make the world "a better place"[23] by improving the global quality of life ("engineers benefitting 'the public'"). The claim suggests a strong service ideal and is supported by a needs-based construct involving two parties. The first is engineers, who possess the ability to build new technologies and apply technological solutions. The second is "the public," which lacks technologies necessary for thriving or, even worse, meeting its basic human needs, and does not have the ability to create these technologies or create technological solutions. In engineers' imaginaries of "the public," "the public" is frequently portrayed as economically disadvantaged, with limited awareness about what engineers do and appreciation for what engineers have achieved ("developing," "lacking information," "poor," "technologically illiterate"). But "the public" is also envisioned as needing and desiring what engineers have to offer: technological interventions that solve problems and advance the human condition ("lacking/desiring technology").

Engineers' characterizations of "the public" render "the public" as *different* or *other* from engineers on three fundamental levels: a) its basic life conditions (i.e., "the public" lacks technologies necessary for surviving or thriving), b) its technical knowledge (i.e., "the public" lacks engineering expertise to meet its own needs), and c) its understanding about the engineering profession (i.e., "the public" lacks awareness about engineers' work and influence on people's daily lives). In other words, it can be argued that engineers' imaginaries of "the public" distance engineers from the people they serve through a deficit construct. The latter highlights resources, knowledge, and skills "the public" is assumed to lack while staying silent on assets "the public" may possess that could complement, expand, or at times even challenge the worldview of engineers. This distancing seems to elicit in engineers two defining sentiments, sometimes possibly in tension:

The first seems to be a desire to *help* "the public" by improving its quality of life through technological innovation and intervention ("solve problems"). This desire is expressed predominantly through articulations of a giver-receiver relationship wherein engineers offer, and "the public" receives, technical expertise. In these articulations, "the public" is rarely portrayed as actively engaged, in a leadership role, or in a position to adjust or improve what it receives through local knowledge and insight. Interestingly, of the 283 segments to which the code "solve problems" was assigned, only 45 (16%) also characterized the relationship between engineers and "the public" as "cross-disciplinary/interdisciplinary/interdependent" or "collaborative," or as involving a public that is "engaged" in the problem-solving process (of all document categories, LTS was more likely to characterize "the public" as "engaged" and the relationship between engineers and "the public" as "collaborative"). In other words, in its perceived role as receiver of engineering expertise, "the public" is imagined as, by and large, eager, passive, and grateful, a feminized depiction that seems to omit strong historical evidence of a more complex reality: of publics identifying problems commonly believed to reside solely in the domain of technical experts,[24,25,26,27,28] uncovering risks posed or harm caused at least in part by such experts,[3,28,29,30,29] resisting technical expert claims or technological innovations and interventions,[31,32,30] making significant contributions to science and engineering solutions,[31,32,33,34] affecting change in science and engineering thought and practice,[36,35,36] and demanding accountability from technical experts as well as a seat at the table where technical decisions are made.[2,29,30]

The second sentiment seems to be a need to *maintain professional authority* in the eyes of "the public," in order to ensure "the public's" trust in engineers as "master builders, environmental stewards, innovators and integrators, managers of risk and uncertainty, and leaders in shaping public policy"[13] ("build/sustain professional image," "increase public understanding," "trusting of engineering profession"). In other words, in their perceived role as so called givers of technological expertise, engineers are imagined as holders of knowledge that renders them uniquely equipped to bring society "progress" by spearheading technologically centered solutions. In this masculinized depiction, engineering perspectives on problems as complex as clean water, sanitation, housing, transportation, food production, environmental pollution, climate change, and sustainability, are given primacy regardless of the conditions creating these problems, the people affecting them and those affected by them, and the problems' location in the world (i.e., in terms of the historical, geographical, cultural, economic, and political forces involved). In this context, cross-disciplinary, interdisciplinary, interdependent, and collaborative relationships with non-engineers are envisioned as potentially useful, and even necessary, under certain circumstances. However, new knowledge generated by such relationships is viewed as subsumable under engineering mind frames.

Although in engineers' imaginaries of "the public" engineering is viewed as interdependent with social, economic, and political forces and is acknowledged as insufficient for singlehandedly improving the global quality of life ("cross-disciplinary, interdisciplinary, interdependent," "collaborative"), engineers themselves are portrayed as free of positionality, able to see "everything from nowhere,"[37] and thus as natural and neutral drivers of humanity's technological advancement ("solve problems," "ensure sustainability," "offer broader training to engineers," "engineers benefitting 'the public,'" "engineers engaging 'the public,'" increasing "social footprint" over time). In this role, engineers are viewed as promising leaders who are equipped to serve as “master integrators”[12] of different types of information and unbiased influencers of policies and actions pertaining to their expertise. Their proactive engagement with societal problems is cast as necessary not only for the realization of the engineering profession’s service ideal, but also for the very growth and survival of the profession:

ASCE, for example, asserts that, “*Clearly the acquisition of leadership skills and the art of practicing leadership are vital to the future of civil engineering*.”[12] Echoing this conviction, the ASCE’s vision is that its practitioners be “*entrusted by society as leaders in creating a sustainable world and enhancing the global quality of life*.”[12] ASME wants mechanical engineers to “*accept a new imperative to take a leadership role in political, social, industrial, professional and cultural arenas to bring the engineer’s perspective to larger social issues*.”[14] NAE promotes a vision of engineers “*who will assume leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry*.”[22] EWB wants to see engineers as “*global leaders*.”[24] And proponents of LTS call for engineers who combine leadership and knowledge “*to tackle some of the most pressing problems of marginalized peoples around the world*.”[23] In other words, engineers’ imaginaries of “the public” place engineers at the helm of solving societal problems.

The implied equivalence between a) strengthening the profession’s status and reach, and b) approaching all problems with an engineering component as primarily engineering problems, while presuming that engineers have the skills to comprehend and integrate non-technical complexities into technically-centered solutions, seems to disregard a well-documented lesson from past engineering mistakes: that privileging engineering knowledge, perspectives, and priorities over and above other knowledges, perspectives, and priorities – and especially the knowledges, perspectives, and priorities of publics engineers aim to serve – can be a short-sighted and perhaps even inappropriate mindset, for it has been associated with engineering failures, public harm, and the perpetuation of multiple forms of injustice.[38,39]

In the end it seems possible, if not likely, that the engineering profession’s desire to help “the public” and maintain authority, when put into practice can draw and redraw a boundary between engineering and non-engineering worldviews that positions the former above the latter, naturalizing an epistemic hierarchy. This hierarchy places the engineering profession in charge of how it serves society, leaving it vulnerable to the circular premise that what engineers do promotes the social good just because they are engineers.[2] It, therefore, seems that at the heart of engineers’ imaginaries of “the public” might lay a paradox. Namely, that the engineering profession’s identity vis-à-vis “the public” may systematically silence public voices, and thus at times undermine the profession’s aspiration to promote the social good in ways that diverse – and especially marginalized – publics experience, recognize, and celebrate as promotions of the social good. By extension, this identity might compromise the profession’s capacity to secure “the public’s” trust in engineers as professionals who can be relied on to, indeed, make the world “a better place.”[23] Exploring this paradox further through study of the histories, experiences, and insights of publics who have been directly affected by the work of engineers, will be necessary for the profession’s service ideal to be better realized.

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Appendix

1. **Characterizations of "the public"**
    a. Consumers [1]
    b. Customers [2]
    c. Developing [3]
    d. Engaged [4]
    e. Entrepreneurs [5]
    f. Expect more from engineering [6]
    g. Lacking information (about engineering/engineers) [7]
    h. Lacking/desiring technologies [8]
    i. Poor [9]
    j. Technologically illiterate [10]
    k. Trusting of engineering profession [11]
    l. Unable to meet basic needs/improve quality of life [12]
    m. Underserved [13]
    n. Unprepared to participate in discussions about technology [14]
    o. Urban [15]

2. **Engineers' "social footprint" over time**
    a. Consistent [16]
    b. Decreasing [17]
    c. Increasing [18]

3. **Engineers' professional duties related to "the public"**
    a. Affect change [19]
    b. Build capacity/empower [20]
    c. Communicate/interact [21]
    d. Consider societal impacts/context [22]
    e. Create a better world [23]
    f. Ensure sustainability [24]
    g. Enter public sphere/public policy [25]
    h. Establish partnerships [26]
    i. Exchange/share knowledge [27]
    j. **Hold paramount**
        - Public health [28]
        - Public safety [29]
        - Public welfare [30]
    k. Increase public understanding [31]
    l. Innovate [32]
    m. Learn from successes/failures [33]
    n. Make technologies available to "the public" [34]
    o. Meet diverse needs [35]
    p. **Practice virtuously**
        - Be equitable/fair/transparent [36]
        - Be loyal [37]
        - Practice ethically/responsibly [38]
        - Practice with excellence/competence [39]
        - Practice with honesty/trustworthiness [40]
        - Practice with impartiality/lack of bias [41]

q. Promote diversity/multiculturalism [42]
r. Promote integrity [43]
s. Promote learning [44]
t. Promote respect [45]
u. Provide opportunities/products/services [46]
v. Remain economically competitive [47]
w. Serve/promote public service [48]
x. Shape the future [49]
y. Solve problems [50]
z. Support cost-effectiveness [51]
aa. Support customization [52]
bb. Support growth-prosperity [53]
cc. Support human welfare [54]
dd. Support local leadership [55]
ee. Support self-reliance/ability to meet basic needs [56]
ff. **Benefit/improve engineering**
    - Build/sustain professional image [57]
    - Develop/support leaders in engineering [58]
    - **Education-related**
        - → Better prepare engineering students [59]
        - → Encourage education in engineering [60]
        - → Offer engineering students broader training [61]
    - Recruit [62]

gg. Volunteer [63]

4. **Relationship between engineers and "the public"**
    a. Collaborative [64]
    b. Cross-disciplinary/interdisciplinary/interdependent [65]
    c. Engineers impacting "the public" [66]
        - Benefitting "the public" [67]
        - Engaging "the public" [68]
        - Harming "the public" [69]
        - Impacting non-engineer professionals [70]
        - Impacting public policy [71]

    d. Justification for the relationship [72]
    e. "The public" impacting engineers [73]
    f. The relationship is not… [74]

5. **Societal problems/issues in need of engineering solutions**
    a. Cost-benefit constraints [75]
    b. Demographic changes [76]
        - Aging society [77]
        - Increase in minority populations [78]
        - Worker-pensioner ration changes [79]
        - Youth bulge [80]
        - Economic infrastructure stresses [81]

    c. Intellectual property [82]
    d. Lack of self-reliance [83]
    e. Moral/religious repercussions [84]
    f. Multilingual influences/cultural diversity [85]

g. Natural resource stresses [86]
h. Physical infrastructure stresses [87]
i. Population changes (overall)
  - Decrease [88]
  - Increase [89]

j. Project management [90]
k. Quality of life [91]
l. Scarce technological resources [92]
m. Social infrastructure stresses
  - Education [93]
  - Health [94]
  - Labor force tensions [95]
  - Political instability/national security/terrorism [96]
  - Unemployment [97]

n. Unspecified challenges [98]

6. **Vision/mission statements** [99]

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