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Engineers' Imaginaries of 'The Public': Dominant Themes from Interviews with Engineering Students, Faculty, and Professionals

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Abstract

This paper is the second of a three-part study on engineers' conceptions of "the public" through the theoretical lens of "social imaginaries." It focuses on dominant themes from semi-structured interviews with engineers about their views of "the public," the role of engineers in society, and characterizations of the "ideal" versus "real" relationship between engineers and "the public."

Interviews were conducted with 43 engineers: 13 first-year and 11 senior undergraduate students, ten engineering faculty, and nine professional engineers with at least five years of work experience. Interview participants represented primarily civil, mechanical, and electrical engineering. All students and faculty were affiliated with two universities and the majority (6/9) of the engineering professionals were alumni of these same institutions. Women (19/43), underrepresented minorities (URMs) (12/43), and students and faculty engaged in Learning Through Service (LTS) (9/43) were intentionally oversampled, as compared to the general engineering population, to capture diverse and possibly non-dominant views within the engineering community.

Interviews were recorded, transcribed, and coded. Two-hundred-and-seventy-nine emerging codes were identified using qualitative data analysis. They were broadly organized for this paper into dominant themes that included a) interviewees' characterizations of "the public," b) experiences that shaped interviewees' views of "the public," c) interviewees' understandings about their role in society, d) interviewees' understandings about the role of "the public" in engineering decision making, and e) interviewees' perceptions of risks and benefits associated with interacting with "the public."

Introduction

At the forefront of the engineering code of ethics is the mandate to "hold paramount the safety, health and welfare of the public"[1]. The National Academy of Engineering (NAE) refers to engineers as "a key force in the improvement of our economic well-being, health, and quality of life," [2] forward-thinking innovators who "make a world of difference," [3] and agents of technical solutions that can "ensure the sustainability of civilization and the health of its citizens, while reducing individual and societal vulnerabilities and enhancing the joy of living in the modern world" [4]. Similarly, most engineering professional societies market themselves with statements centered on their contribution to society like "Advancing Technology for Humanity" [5] and "ASCE stands at the forefront of a profession that plans, designs, constructs, and operates society's economic and social engine…" [6]. The relationship between engineers and "the public" sits at the very core of engineers' professional identity and public mission and, largely, is a relationship which is poorly understood and has been under-studied.

Gaining a deeper understanding of the relationship between engineers and "the public", namely how engineers conceive of "the public," was the impetus for the broader study that this paper is a part of. There are myriad historical and modern examples of engineering failures where the public was harmed or placed at risk of harm due to engineering decisions: some examples include the lead-in-water crisis in Washington, DC from 2001-2004 and Flint, Michigan from 2014-2015, complacency with respect to defective General Motors vehicles which led to 30 deaths and 31 injuries between 2003 and 2014, and decisions made by engineers at Volkswagen

to program certain vehicles to give false emissions records during testing from 2008-2015. Rather than seeing these examples simply as unethical decisions made by individual engineers, these may represent evidence of systematic and persistent disregard for the public safety, health and welfare that is rooted in the ways that engineers conceive of "the public."

We posit that engineers generally see "the public" as an imagined entity when making critical decisions that reside in complex social contexts. The risk of operating only with imagined publics is that engineers then work and make decisions within a narrowed understanding of "the public", who "the public" is, what their priorities are, or what risks they are willing to take with respect to possible engineering solutions. Answering these questions in a relative vacuum opens engineers up to the risk of making gross miscalculations on behalf of "the public," leading to failed engineering solutions, wasted money, and potentially significant harm to members of the public. Furthermore, working only within the scope of an imagined public can create an environment with artificial separation between the engineer and those they intend to serve, creating a dangerous "us" versus "them" environment where "the public" is seen as the enemy.

We have approached this study through the theoretical framework of "social imaginaries," which focuses on the "making sense of" the social order, expectations and boundaries that shape the negotiated relationship of one group with respect to another [7]. These negotiated boundaries are oftentimes unspoken and unseen, yet they represent relational norms that are expressed not only by how things are, but also in beliefs about how things "ought to be." These boundaries are seen through discussions of the norm and also characterizations of missteps, where the boundaries are crossed. Social imaginaries are engrained in the engineering profession itself and would be passed on through formal and informal processes in the training of engineering students and through the professional practice of engineers [8]. Who defines the boundaries between engineers and "the public", how they are enforced, what happens when they are violated, and what ramifications come from the defined boundaries are central questions that deeply affect the relationship between engineers and "the public" and can be better understood through this lens of the social imaginary.

This paper presents preliminary results from the second of three components of a larger study focused on understanding engineers' social imaginaries of "the public" [9]. The first part focused on dominate themes from content analysis of foundational engineering documents and found that messages promoting engineers as benefitting society and as problem solvers were in the forefront as to how engineers envisage themselves in relation to "the public" [10]. "The public", however, was often characterized as unknowledgeable and unprepared to participate in the process; largely represented from a deficit-based rather than an asset-based perspective. The second part of this study (this paper) focuses on interviews with engineering students, faculty and professionals focused on understanding and defining their imaginaries of "the public." The third part of this study will focus on interviews with members of "mobilized publics" [11], people who have been involved in social struggles that included engineers as advocates, opposition or both. Community members who were involved in the Flint, Michigan water contamination case, the Washington, DC water contamination case and various environmental contamination cases around Buffalo, New York were interviewed about their views of the relationship between engineers and "the public." The following sections detail the methods and results from the interviews with engineering students, faculty and professionals.

Methods

Stratified purposeful sampling [12] was used to select participants for the interviews from two universities, specifically oversampling for women, underrepresented minorities (URMs) and for participants who had been active in Learning Through Service (LTS). A summary of the participant demographics for this study are shown in Table 1. One of the institutions was a small, private, religiously affiliated university (Small Private U) located in a large urban center on the west coast. The second was a large, public, research-intensive technical university (Large Public U) located in a rural setting on the east coast. These settings were chosen primarily due to convenience because of easy access by the researchers but they also represent very diverse institutional cultures for comparison.

Table 1. Interview participant demographics

Sample Population	Total	Small Private U	Large Public U	Female	URM	Active in LTS	Engrg. Discipline		
							CEE	ECE	Mech.
First-Year Undergrad. Students	13	6	7	5	1	2	1	4	5
Senior Undergrad. Students	11	5	6	5	4	3	6	3	2
Faculty	10	5	5	4	4	4	5	1	2
Professional Engrs.	9	4	2	5	3	N/A	6	2	1

URM = Underrepresented Minority; LTS = Learning Through Service; CEE = Civil/Environmental Engineering; ECE = Electrical Engineering/Computer Science

First-year and senior undergraduate engineering students were targeted with the intention of bookending the undergraduate experience and, hopefully, to provide a comparison of possible trends in changing views over the undergraduate experience. To recruit undergraduate participants, solicitation emails were sent out through departmental email lists at both institutions asking students to participate in a one-hour interview about engineering education. The email also disclosed that members would be paid $50 for their participation. Nineteen students responded from Small Private U and 11 were selected to participate based upon the target demographic distributions and schedule availability. Fourteen students were selected at Large Public U based on similar criteria – demographics and schedule availability. All student interviews were conducted in person with one or both of the researchers present.

Engineering faculty were directly contacted and asked to participate based on the researchers' knowledge of the faculty at each institution and, at Large Public U, also through snowball sampling from faculty initially asked to participate. Faculty were approached based upon their discipline, years of experience, gender, and LTS involvement to try and capture diverse backgrounds. All of the engineering faculty were tenure-track faculty ranging from assistant-professors with a few years of experience to full professors with decades of teaching experience. When asked to participate, faculty were given the title of the study, that it was funded by NSF and that they would be paid $50 for their participation. All of the interviews were conducted in person except for one which was conducted remotely via Skype.

Professional engineers were solicited through recommendations from faculty at each institution and through professional connections of both the researchers. Initially, alumni from each institution were sought and then snowball sampling was used to find two more participants. Similar to the students and faculty, participants were told about the title of the study and the $50 incentive to participate. Interviews were conducted in-person (5) and remotely via phone or

Skype (4). Professionals were selected to represent both public and private engineering practice, multiple engineering disciplines and varying lengths of professional experience - all more than five years.

Interviews were all semi-structured, using the same interview questions for the students and faculty with some adapted questions for professionals to relate to their practice more than their educational experience. The bulk of the questions were open-ended, focused on views of themselves as engineers, of "the public" and experiences with "the public." An additional element of the interviews had participants read a news article related to a community's belief that their air was being contaminated by a local industrial facility and conflicting tests from government and local organizations about the air quality. Participants were asked to read the article and then provide their initial reactions and what recommendations they would make. Finally, participants were asked to define four terms (social responsibility, social justice, activism, and citizen science) and to discuss how, if at all, they related to engineering. All interview questions are presented in the Appendix. Participant responses regarding the article, definitions and a few other open-ended questions noted in the Appendix are not included in the analysis presented in this paper. All interviews lasted between 30 and 90 minutes and were audio recorded and transcribed for analysis. All participants filled out an informed consent form prior to the interview, conforming to Institutional Review Board protocols, and all participants were paid $50 at the end of the interview for their participation.

Coding

Interview transcripts were coded using emergent thematic coding organized broadly by the interview questions. Participant responses to one question that bled into themes from other questions were coded in both categories. The codebook was initially developed by one of the researchers based on a sub-set of interviews and then expanded by the second researcher using all of the interviews which formed the basis for this preliminary analysis.

Results

Guided by the interview questions, the codes and results are clustered in relation to the following broad categories: a) interviewees' characterizations of "the public," b) experiences that shaped interviewees' views of "the public," c) interviewees' understandings about their role in society, d) interviewees' understandings about the role of "the public" in engineering decision making, and e) interviewees' perceptions of risks and benefits associated with interacting with "the public."

a) Interviewees' characterizations of "the public"

All participants were asked the following questions pertaining to characterizations of "the public":

- Thinking broadly, who is the public and how would you characterize the public?
  - What knowledge or capacities does the public hold that might be relevant to engineering?
  - What deficits does the public have with respect to engineering?

Other data came from respondents' answers when sharing past experiences interacting with "the public" as engineers, experiences that have shaped their views and also when characterizing engineers, which was often housed in contrast to a characterization of "the public." Characterizations of "the public" are discussed in two ways, first in relation to how participants

defined who "the public" included and second with respect to attributes that participants ascribed to their defined public.

Answering the question of "who is the public" was difficult for most participants. The vast majority (n=36) of the interview participants responded that the public is everyone and oftentimes they explicitly included engineers or themselves as members of the public (n=17). Seven participants explicitly talked about engineers as separate from "the public," typically describing themselves as having two separate and distinct identities – one as an engineer and one as a member of "the public." One participant said: "I mean, sometimes [the public] can include me too. I mean, if there is some development that is coming close to my home, I remove my hat as an engineer and now I'm a home owner..." At another point in the interview, this same participant elaborated on this role switching, giving an example related to development of local public transit systems:

> "…sometimes [I'm] seeing on the side to the engineers, looking at the public, and sometimes I'm on the public's side when they're talking about, okay [transit company] train service is coming close to my home and now I'm wondering how it is going to impact my neighborhood. The engineering project's close by, but now I'm the user of the house value and property value – now I'm more interested in being the public side."

The next most common answers to who "the public" were included definitions of "the public" in relation to engineers' work. These categorizations included "the public" as customers-consumers-users (n=25), clients (n=17), as anyone who is affected (directly or indirectly) by engineers' work (n=13), simply as "diverse" (n=11), or as funders of engineering work (n=6). Comparing across demographics showed few differences based on gender, URM status or LTS participation. Participants from Large Public U were more likely to use the term "clients" than participants from Small Private U (75% vs. 11%), though they were similarly likely to use customer-consumer-user. Senior engineering students were more likely to define "the public" as anyone who is affected by engineers' work (70%) than first-year (21%), faculty (0%) or professional (33%) participants.

The common characteristics of "the public" that were discussed by participants can be clustered as assets/strengths and deficits/weaknesses. Thirteen codes emerged for participants' responses to the question about knowledge or capacities of "the public" which might be relevant to engineering or as positive characterizations of "the public" in response to other questions. Thirty-one codes emerged about deficits of "the pubic" in relation to engineering or as characterization of "the public" from a deficit perspective. The codes pertaining to assets/strengths and deficits/weaknesses of "the public" with five or more respondents are shown in Table 2 along with sample quotes for each.

Table 2. Common codes pertaining to assets/strengths and deficits/weaknesses of "the public"

Code	Total N=43	Sample Quote
Asset/Strength		
Experiential Knowledge/ Observations as an asset	27	"So, I would say really like historical knowledge, particularly in places I go, it's extremely important. Like in Alaska or last year, the Arctic, like what the local clans and tribes know, I mean, they know about like when the tsunamis were. They have all these mouth-to-mouth and sometimes written records… there's a lot of knowledge there, historical heritage knowledge."
Knowledge of priorities/ needs/ wants as an asset	21	"I think that the public certainly has viewpoints and understands some content better than engineers in general. So public, the public can offer insights into their priorities. We might prioritize as engineers something which might not be related to or might not be accurate when it comes to what the public actually wants."
Not lacking information/ knowledge/ education	12	"… most people have an incredible intuition of how things work and, you know… they may not be able to calculate X, Y, Z, but they understand that if you change X, that's how it would affect Z."
The public can produce new science/ knowledge or be innovative	6	"I just think like the public enters or offers a huge opportunity for [software development] and is kind of able to maybe even help develop them just through, like, learning from the company or learning from the public…"
The public can learn or be taught as an asset	6	One participant shared a story about running workshops and creating tutorials around a community-based development project, where the local community was developing the capacity to operate the project after they left. "we… create nice little teaching videos and hand that over to the community…"
Deficit/Weakness		
Lacks information about engineering	22	"I think there's a mix of people. There are people who really understand what engineering is, what engineers do, and then there [are] people who have no idea what we do…"
Lacks information generally	21	"I think one of the problems with the public is they have no idea what's going on, I mean, I used, and this isn't to think I'm a genius or anything, but I used to think that like the regular everyday American and, over the years, I've come to the realization that I don't think we're [engineers] anything like normal American. I mean we think about things. We have more knowledge. We have more reading."
Is technologically illiterate	17	When characterizing the public: "a large percentage of the population, right, I mean most people have no clue about how 911 works. Most people have no clue how we get power to the buildings, you know… the public doesn't have a clue about what's going on around them…"
Lacks knowledge or education	16	"… I don't wanna say most people are very tolerant or educated in general management [chuckles]."
Lacks engineering knowledge	15	"I think the public, generally, I mean, they're not engineers, so they don't understand, so, I'd say the technical aspects."
Is emotional or illogical	10	"[the pubic] don't have the same education that the engineers have and I think first response to emotion instead of logic is probably something."
Has unrealistic expectations	10	"I think these people [the public] think we're miracle workers. That you can, if there is something that 'can you do this?' and you go 'no' and they're gonna go 'why not?'"
Makes uninformed or short-sighted decisions	10	"now I think this is philosophical I guess but I think the public has very little appreciation for… the public is very… Everyone not everyone is about instant gratification you know following in dadada so I think we've lost this this appreciation that… Engineering and infrastructure to benefit society requires investment you know that that's investment in education or that's investment in resources I think that I think there's a disconnect there and, and you know I think I think people think about engineers or engineering or science about creating the next newest thing but they

		don't think about fixing or maintaining everything that makes it possible to create the next different thing so there's that I think that's a huge disconnect"
Is vulnerable to manipulations	8	When talking about resistance to civil infrastructure development: "…there's a lot of influence, right, with the government politics and all that, so people are influenced by that because of the political, of the religious beliefs and so on. That definitely is a part of, and sometimes people can't think for themselves, they are always influenced by others, can be friends, family, it's sometimes a pastor, right?"
Lacks or desires technology	7	"Well ultimately I would say… Engineering you can view it as a business… And businesses are based on supply and demand and if there was no demand for phones that were smaller, faster, brighter, cooler gadgets and gizmos then there would be no reason or no financial reason to pursue improving them but because of desires of the public we improve those things"
Is obstructive of engineering work	6	"Well yeah certainly there are troublemakers there's no question and you gotta work with the troubles maker just like in our classes I mean you have trouble and you put them aside and start time with them what's the problem you know and then and then… You know I don't know what the way is to calm them down you've got to find a way to calm them down."
Lacks knowledge of engineering jargon - language	5	"…it's really hard to tell, it's strange, because I think sometimes, I mean I think this is true in various professions, because everyone invents jargon and lingo that makes it more inaccessible to others, but I think it's, I think sometimes engineers assume the public has a deficit in the ability to even understand what technology they're using…"

Table 3 presents the breakdown of code prevalence by demographic categories as a percentage of the total number of participants within each category. The largest differences for codes around assets and deficits of the public for each demographic group are highlighted. Participants from Small Private U were more likely to talk about "the public's" lack of information about engineering, while participants from Large Public U were more likely to characterize "the public" as emotional or irrational and also more likely to highlight experiential knowledge and a capacity to produce new science or knowledge as assets. Women were more likely to refer to "the public's" knowledge of its own priorities or needs as an asset than the men who participated, as were URM participants over non-URM participants. Participants who had been involved in LTS were more likely to characterize "the public" as being able to learn or be taught, but also about "the public" as lacking or desiring technology. Faculty participants more often talked about "the public" as not lacking knowledge or information generally, and also as technologically illiterate and lacking or desiring technology over the first-year, senior and professional participants.

Table 3. Assets/strengths and Deficits/weaknesses of "the public" code prevalence by demographic category (%)

Code	Institution		Gender		URM		LTS		Position			
	Small Private U	Large Public U	Male	Female	Yes	No	Yes	No	1st Year	Senior	Faculty	Professional
n =	18	20	24	19	12	31	9	33	14	10	10	9
Asset/Strength												
Experiential Knowledge/Observations as an asset	56	70	67	58	58	65	67	64	50	80	60	67
Knowledge of priorities/needs/wants as an asset	39	50	38	63	75	39	44	52	29	70	40	67
Not lacking information/knowledge/education	39	25	38	16	17	32	44	24	0	40	70	11
The public can produce new science/knowledge or be innovative	6	20	17	11	0	19	11	15	7	10	20	22
The public can learn or be taught as an asset	17	15	17	11	17	13	33	9	21	10	20	0
Deficit/Weakness												
Lacks information about engineering	67	45	54	47	67	45	67	48	43	50	80	33
Lacks information generally	61	40	54	42	33	55	67	45	43	30	80	44
Is technologically illiterate	56	35	50	26	33	42	56	36	50	10	80	11
Lacks knowledge or education	44	30	42	32	25	42	33	39	43	0	60	44
Lacks engineering knowledge	28	40	38	32	17	42	22	39	36	40	0	67
Is emotional or illogical	11	40	29	16	8	29	11	27	36	0	40	11
Has unrealistic expectations	11	30	21	26	25	23	33	21	7	20	30	44
Makes uninformed or short-sighted decisions	22	25	29	11	8	26	44	15	7	0	60	22
Is vulnerable to manipulations	28	15	25	11	17	19	44	12	21	20	30	0
Lacks or desires technology	17	20	21	11	25	13	44	9	0	0	70	0
Is obstructive of engineering work	11	10	8	21	17	13	0	18	7	0	30	22
Lacks knowledge of engineering jargon - language	6	20	17	5	8	13	11	12	7	30	0	11

Note: Shaded cells mark the largest difference in code prevalence within each demographic group

b) Experiences that shaped interviewees' views of "the public"

All interview participants were asked the following questions about experiences that may have influenced their views of "the public."

- What experiences have shaped your views of the public?
- How has (did) your education shaped your views?
- Have you ever had any experiences interacting with the public as an engineer? If yes, describe an experience that was good and one that was bad.

Nineteen codes emerged with respect to participant experiences that have shaped their views of "the public", 13 of those were education related (codes with five or more participants shown in Table 4).

Table 4. Common codes pertaining to experiences that influenced participants' awareness or views of "the public"

Code	Total N=43	Sample Quote
Experiences that shaped views of the public		
General life experiences	27	"I've visited a lot of schools given talks, I've given presentations to I don't know 30 Rotary clubs that's maybe somewhat of a self-selecting group of the public but just other… riding the bus [laughs]. Mostly just through giving presentations and interacting with people…"
Education – makes you conscious about engineering as service to the public	22	"I think from my perspective and then quote unquote back in the day in ag. engineering you know we knew we were dealing with people in the land and so that was the public that we were serving so that was more of the identification that I got other than you know like this public at large it was that audience that we were serving from the perspective that that that it came from our profession."
Education – is silent about the public	19	"Never… my undergraduate educational was highly technical. We had some classes on laws and things like that but only from a strict perspective - no socioeconomic things or anything like that in my graduate education… no. Anything that I have learned or trying to learn has been from my personal efforts to learn more and from conversations with colleagues…"
Interactions as a practicing engineer	16	"Yeah that's that goes back to that kind of experience in that humbling effect of going out and seeing a job site and thinking you have that idea of what the reality of what you're doing is and then going to a job site and just being totally you know 180° off. Going and talking to people who have you know still their own kind of perspective right"
Education – awareness through ethics or codes of ethics	13	"You know I think we had, there were courses where we talk ethics courses and those kinds of things, talking about, you know, code of ethics in engineering and I think that's kind of the one aspect you have, but again I think from my perspective and then quote-unquote back in the day in agricultural engineering, you know, we knew we were dealing with people in the land and so that was the public that we were serving so that was more of the identification that I got…"
Education – awareness through a lens of safety	11	"We talk a little bit about engineering ethics I think for like two days and just how it's our responsibility to make sure we consider repercussions of what we do instead of just making this scientifically best thing to actually make sure the public can use it and it's safe and that it's manufactured correctly so that everything turns out okay."
Education – doesn't foster well-roundedness	7	"professors are teaching them to be doing the hard stuff only and not telling them that yes you do have to write well and you have to have good presentations and you have to tweet and you have to communicate with the rest of the world what you're doing and explain to them the benefit of your work"
Education – offers minimal contact with the public	7	"Um so I would say there is not a whole lot [of experiences] at the undergraduate level because it was pretty much you know classroom [work]…"
Have had increased awareness over time	6	"Anything that I have learned or trying to learn has been from my personal efforts to learn more and from conversations with colleagues but in order to completely honest… The role the public and the importance of the input of the public started growing in me as an interest when I saw that as a professor I cannot get any funding unless I proved that my research is important for the public and that that is important because you see that NSF and other funding organizations push us to start thinking about the public so you know… I have started you know informing myself more and more."
Education – teaches about the public through interactions with peers	5	"I'd say it's just from like my friends and just talking to people like because everyone has their own like perception of different things so but they're all seeing like the same general thing but in just different ways so maybe that's how I got like a view of the public just from talking to people."

The majority of participants (27 of 43) pointed to general life experiences such as following political issues including science (e.g. nuclear energy or climate change) or "watching people interact with technology" as the main source of their views of the public. Sixteen participants talked about their interactions with members of "the public" through engineering jobs or internships as being influential and three participants were unsure or didn't answer the question.

Service to the public (n=22), codes of ethics (n=13) and safety (n=11) were common mechanisms used in participants' educational experiences that influenced their views of "the public." Others talked about the absence of "the public" from their education (n=19), a lack of well-roundedness in their education (n=7), minimal contact with "the public" during school (n=7), how their education creates segregation between engineers and "the public" (n=3), fosters arrogance in engineers (n=3), or portrayed "the public" as dumb or irrational (n=3).

Participants from Large Public U were more likely to talk about both their educational experience as making them aware of the public that they serve compared to participants from Small Private U (65% vs. 39%). Female participants were more likely than male participants to talk about their education being silent about the public (58% vs. 33%) and about experiences as practicing engineers that influenced their views of the public (53% vs. 25%). Professional participants were least likely to point to general life experiences than student or faculty participants (professionals - 22%, first-year – 79%, senior – 70%, faculty – 70%), but were more likely to talk about interactions as practicing engineers (professionals - 89%, first-year – 0%, senior – 20%, faculty – 60%), which makes sense. First-year students were most likely to talk about learning about the engineering codes of ethics as influential (first-year – 57%, senior – 40%, faculty – 10%, professionals – 0%) and none of the professional participants talked about the codes of ethics as influential to their views of "the public." URM participants were more likely to point to interactions as practicing engineers than non-URM participants (58% vs. 29%) and LTS participants were more likely to talk about how their education provided minimal contact with the public than non-LTS participants (44% vs. 9%). Non-LTS participants talked more than LTS participants about interactions as practicing engineers as being influential (42% vs. 22%).

Seventeen of the 43 participants said that they had not had any experiences interacting with "the public" as engineers (9 first-year undergraduate students, 4 senior undergraduate students, 3 faculty members and 1 professional). From participants who did have interactions with "the public" as engineers, 17 codes emerged in participants discussion of good (10 codes) and bad (7 codes) experiences interacting with the public (codes with five or more participants shown in Table 5).

Table 5. Common codes pertaining to descriptions of good and bad experiences interacting with "the public" as engineers

Code	Total N=43	Sample Quote
Good experiences interacting with the public		
Public having benefitted	11	"Yeah sure so in the context of some of the work that I do with [LTS organization]… It's great to do an installation [of a solar energy system] and to go and visit the people that are benefiting from that installation…"
Public was eager to learn or get involved	11	"After about five years of us demonstrating this as a safe source of water, it's great, it's drought-tolerant, they are drought-resistant, we got public - quite a number of public people were actually banging on the door "Hey, we're in a mini-drought, can we get recycle water cause we may get cut off and we're worried about that." It was really exciting to be part of that… We were actually out there in field, when we're doing the construction and folks were walking by that's really excited, wondering why this didn't happen sooner."
Public was grateful	10	
Feeling helpful to others	8	After describing a project, a participant responded when asked what was positive about the experience, "Well it's rewarding for me… I would say…um… You know I enjoy… Helping other people and putting my skills to use to benefit other people."
Bad experience interacting with the public		
Members of the public were angry, ungrateful or frustrated	15	"I remember one summer doing construction inspection and we were there all summer. We took a few lanes of a six-lane road and people were honking and swearing at us during construction even though it's for their own betterment and good as part of the community."
Sub-optimal communication between engineers and the public	9	"The perception is, you know, my perception as well if we just talk this through I can we can probably come to a point where you can understand that this really probably is beneficial for everything but so it's not so much engineering it's just communication, right, which I think some engineers have problems with. I probably have a problem with it sometimes too. It's just that the frustration comes when there's a lack of communication and there is no opportunity to alter perceptions you know whether or not people don't want to hear the details about the perception or they're just mindset is just I don't want to I don't want to change my those are the those of the frustrating times."
The public lacking information	5	

The most common elements among positive experiences that the participants described included the public having benefitted from their work (n=11) and feeling helpful (n=8), the public as eager to learn or to get involved (n=10) and the public being grateful (n=10). Among those participants who had had experiences interacting with the public as engineers, there were few differences by institution or gender. All of the faculty respondents with experiences interacting with "the public" mentioned benefitting the public as a reason for the experience being good, compared to only 25% or less from the professional engineers and students. URM and LTS respondents were also more likely to mention benefitting the public than non-URM (56% vs. 35%) and non-LTS (67% vs. 37%) participants. LTS participants were also more likely to mention the public being grateful as an element of positive experiences than non-LTS participants (67% vs. 32%).

The most common elements among negative experiences included interactions with members of the public who were angry or ungrateful (n=15), poor communication between engineers and the public which oftentimes led to challenging projects (n=9), or the public lacking information (n=5). Participants from Large Public U were more likely that participants from Small Private U to refer to the public being angry or ungrateful (70% vs. 45%) and sub-optimal communication

between engineers and the public (70% vs. 18%). Faculty participants were also more likely to mention sub-optimal communication than professionals (71% vs. 13%) and LTS participants were more likely than non-LTS (67% vs. 26%). All other comparisons were similar between demographic groups for descriptions of bad experiences with "the public."

c) Interviewees' understandings about their role in society

All interview participants were asked directly what the role of engineering is in society or how engineers affect society through the following questions:

- What is the role of engineering in society? How do engineers affect society?

Five codes emerged with respect to participants' understanding of the role of engineers in society. Benefitting society, solving problems or protecting society was the most common response to engineers' role in society (39 of 43) and was the most universal of any code among the 43 participants from the entire code book. This parallels what was seen in the content analysis of foundational engineering literature from part one of this study *[10]*. The second most common role for engineers in society was to provide material goods (n=20). Sixteen participants characterized engineers' role in society broadly as creating the conditions needed for "the public" to thrive ("[Engineers] make everybody's life better. I can't imagine the world without engineers, it would be very primitive, possibly living in caves I guess."). Six participants talked about engineers' responsibility to help educate "the public" as part of their role in society. One professional engineering participant share about the role of engineers in society, saying: "When we [engineers] get a chance to speak with people outside of the profession to be able to educate them as to why we do what we do, whatever that is…they all need to be educated so that they understand why we need to make the decisions that we need to make."

Examining difference among participants' views of engineers' role in society by demographic group showed few variations. First-year undergraduate students were more likely to refer to engineers' role to provide material goods (first-year – 71%, senior – 40%, faculty – 40%, professionals – 22%). Only non-LTS participants' responses were coded with "creating the conditions needed for the public to thrive" (48%) or the need to educate the public (18%).

d) Interviewees' understandings about the role of "the public" in engineering decision making

Similar to how participants were asked to describe engineers' role in society, they were also asked to discuss the role of "the public" in engineering. The following questions were asked of all participants:

- What is the role of the public in engineering decision making?
  - To what extent should the public have a voice in engineering decision making?
  - At which stages of the engineering design process?
  - How far is too far for public involvement? Give an example.

Table 6 shows codes related to how participants described appropriate roles for "the public" with respect to engineering decision making. In total, 14 codes emerged describing how engineers see the appropriate role for "the public" - only codes that were present for five or more participants are shown. The need for "the public" to define their needs or problems for engineers to solve was the most common role described for "the public."

Table 6. Common codes pertaining to engineers' views of the role of "the public" in engineering decision making

Code	Total (n of 43)	Sample Quote
Define problems/needs	34	"I think [the public] are the ones that bring light onto issues that need to be resolved [by engineers]"
Generic statements that the public should have input	18	In response to the extent that the public should have a voice in engineering decision making: "Oh boy, tough one. I think they need to have some. It's a question of how much you give…"
The public should serve as a check for engineers	14	"I think it should play very significant role in terms yeah because the feedback is the most important thing at the end of the day the public is the one who's using it which is actually everybody so if the users do not voice out their concern who's going to tell us if this thing is perfect or not or if it's good enough or not?"
The public inserts important contextual knowledge	13	"They are the final users so I think their input is important in making decisions they might know more about certain localized issues that we are not aware of"
The public should have input on issues that directly affect them	10	"I think that would have to depend on… How significantly the engineering decision-making affects them or not like if we're talking about rebuilding a bridge on 81 or 77 or some kind of highway I think the public should have input in that because that's gonna affect people going to and from work or to and from school or whatever they're doing in their lives… And but when you yeah, I think those kinds of projects that really affect people, their daily lives, I think the public should have input into that."
Fulfill the 'funder' role	9	"If the public is ultimately paying for it, like a bridge, then the public should have their decision on how to best spend the money."
Support engineering innovation	9	"I'd say… a limit [on public input], I think in criticizing like the different designs that engineers are brainstorming I don't think they should necessarily have a say in that like they can have opinions that they can like voice but they shouldn't be able to say like no that's just a terrible idea because if there is a bunch of calculations behind that one idea and they just don't understand them then it could be detrimental cause that could be like the one solution that works the best."
Define moral/ethical bounds	8	"I think there's almost like a balance, like I think the engineers should have the overall say in what goes on in whatever they're making or producing, but I think I think the public definitely should have a say in what they want and especially if it has to do with ethics you know"
The public's role is limited by their technical knowledge	5	"Clearly the public shouldn't be involved in in things that they don't necessarily understand the physics or the calculations behind…"

Comparing code frequencies by demographic groups showed that women were more likely than men to say that the public should have input on issues that directly affect them (47% vs. 4%). Only 56% of the professionals interviewed talked about the publics' role as defining problems or needs as compared to 93%, 70% and 90% for first-year students, senior students, and engineering faculty, respectively. None of the professional engineers said that the public should serve as a check for engineers, while over half of the first-year students mentioned this role. Half of the faculty participants cited the role of the public as a funder, but only 7% of first-year students, 20% of the senior students and 11% of the professionals cited the same. This could be because of the view of federal money as the source for research grants for faculty, although tax dollars also fund many civil infrastructure projects, so this was surprising to not also see among the professional engineers. The professional engineering participants were most likely to use vague statements saying that the public should be involved (78% vs. 43% for first-year, 50% for senior and 0% for faculty). A larger percentage of the URM participants cited the role of the

public as supporting engineering innovation than non-URM participants (42% vs. 13%). Among LTS participants, seeing the role of the public as a funder was more common than among non-LTS participants (56% vs. 12%) and non-LTS participants were more likely to use generic statements that the public should be involved that the LTS participants (52% vs. 11%).

When asked to describe the ideal relationship between engineers and "the public," the most common theme was that the relationship ought to be collaborative with bidirectional communication or culturally appropriate solutions (n=24). Participants talked about the need for engineers to be informed about the public (n=18) and for the public to be informed about engineers (n=16). Fifteen participants talked about the need for engineers to listen to the public or to develop forums where engineers and the public could exchange information (n=14). Two descriptions of the ideal relationship are:

> "A collaborative, yet engineering led approach where people - all have a voice. That there are multiple drivers that have to be addressed, and also recognize - trying to create a nice... well-mannered, everybody getting along happily together kind of atmosphere, it's not the engineer versus public kind of thing. Trying to avoid that duality."

> "I will say ideally, it's engineers do what they can to ensure that the public -- that they satisfy the public's expectations of them. And then, likewise, I mean, the public expects that engineers do what's in their best interest. So, ideally, it's a synergy I guess, you know, of the two parties, you know, kind of more of a hip-to-hip type thing of involvement where you know, the public has a defined expectation that the engineers try to achieve and then engineers learn that expectation by involvement with those people."

After describing their ideal relationship, participants were asked how that ideal compared to the current reality of the relationship between engineers and the public as they understood it. The majority talked about there being disconnect between engineers and the public (n=28), characterized by sub-optimal communication (n=13) or solutions (n=6), where engineers don't listen, are self-centered or prideful (n=10). One professional engineering participant described the difference between the ideal and reality, saying:

> "I mean a lot of the times, agencies don't like to engage the public because they see that it's gonna be too long of a process and it takes too long and so we end up, pretty much just designing a project then going into construction then, and informing them right after the design and right before construction and most people are surprised that the projects are coming up or don't even know about it until it directly affects them during the course of the project. So, I can see their hesitation on that end but, I understand why some agencies don't bother because they see that it's going to be more of a headache throughout the process. And sometimes it would just completely stop it - the process."

Nine of the 43 participants felt like the current reality was the ideal relationship and that there were minimal differences. Some participants pointed to the public's deficits such as the public being obstructive or antagonistic (n=7), the public lacking information or being unreliable (n=7), angry or irrational (n=5), self-serving (n=3) and not trusting engineers (n=3).

e) Interviewees' perceptions of risks and benefits associated with interacting with "the public"

After participants talked about the ideal relationship between engineers and "the public", and their perceived differences between that ideal and the current reality, they were then asked to discuss the benefits and risks associated with the ideal relationship. The following questions were asked of all participants:

- What are the potential risks of this interaction between engineers and the public?
- What are the potential benefits?

Sixteen codes emerged related to the potential risks that the interview participants saw with their ideal relationship and 12 codes emerged in response to the potential benefits (codes with more than five respondents shown in Table 7).

Table 7. Common codes pertaining to engineers' views of the risks and benefits of the ideal relationship between engineers and "the public"

Code	Total (n of 43)	Sample Quote
Risks associate with the ideal relationship		
Work is hampered or design is inefficient	20	"Risks - I think one of the risks is, you know, if you listen to everyone you're never going to get anything done so… projects costing more and not happening or taking longer because you're listening so much [to] public input that it really bogs down the process…"
Dealing with disappointed or angry members of the public	16	"Potential risks would be [each] party coming with different expectations or thinking that because they're sitting at the table, everything they say is gonna be heard... The risk is that they might leave disappointed that 'oh I said that to the engineer and he or she did not listen to me'"
Too many voices	14	"It's also important that the communication represent the views of the end user appropriately so sometimes you know the squeaky wheel gets the grease, so there's one opinion that's loud maybe drowns out other opinions even though the other opinions represent the majority and that's a potential problem in my mind."
Dealing with unrealistic, impractical or inefficient expectations	11	"We had a project with we brought in from the very beginning… some end-users…, you know, not engineering people through the whole process. And the challenge was stopping to explain why…that's not really a viable solution, or why that's not technically feasible, or why that's not a direction you want to go. And continually having to do that to the point where that was a constant stream eventually you have to say, 'okay we're going to have to move on.'"
The engineer being misunderstood, misquoted, or misrepresented	9	"Of course, there is some risk if you're kind of going into like a hostile environment and your kind of taking some very unpopular initiative to a neighborhood or to the public there is a risk involved... if you're a very unpopular person, anything that you say can be twisted and put in the news social media."
The public is critical of engineers	7	"Yeah definitely get in risk of having people be very passionate against your thing when it might not really be that wrong"
The public makes poor decisions	7	"There is a risk that the public doesn't actually understand what you're trying to communicate to them and the public makes a poor decision."
Engineers lose their objectivity	5	"I guess [a] risk is that you might fall into traps that people convince you about things like that are actually not true. That you get a little bit from your neutral perspective, how you get pushed away so if you like them like if you like a community too much but actually the decision should be that the structure should not go there because technically it's not the most feasible location but you still think how you want to help these guys then it's - so I think that's a risk. That you lose the objective perspective."

Benefits associated with the ideal relationship		
Better engineering decisions, products or productivity	29	"Because as an engineer you are making better informed decisions on your design, you have heard from your stakeholders, in my opinion I think that's an important thing you have your designing for the public so you definitely need that feedback."
Can foster informed members of the public	18	"Well-educated public as well as engineering staff, so each side understands the challenges and issues, and so that ultimately you can come to a solution that meets everybody's needs as best as they can"
Can foster informed engineers	16	
Can bring engineers and the public into direct communication	15	"Benefits to me is just that the wealth of opportunities in communication right now you can communicate from many different media with telephone, Skype, video, emails, texting and you can increase productivity because of that."
Can lead to a better use of funds	11	"Well I think any time you listen and get more perspectives, especially diverse perspectives, your project could be better at the end. So, you can make more people happy, better suited its objective, it could be a better use of public money for example."
Can bring greater public satisfaction	9	"Both parties are involved. They understand why decisions were made. When [a] decision is made, it may not be universal but it's understood. You don't have that potential reaction after the decision. You kind of get all that up front. There [are] people involved, people understand, people make informed decisions and you kind of move on and I think that would be a huge benefit because if there's a process to anybody, there's no disappointments you know"
Can foster greater public involvement	8	"Well whoever comes from the public… would get informed about the procedure. They would be more involved in the procedure of making decisions and they would actually see all of the things that are involved behind even creating a building or something, or a bridge, or all of the disciplines involved so that increases awareness and appreciation."
Can bring greater satisfaction for engineers	6	"I think it's very rewarding for the engineer… to see your work implemented and helping to address issues and that's gratification"
Can create greater public appreciation for engineering	5	"Well whoever comes from the public… would get informed about the procedure. They would be more involved in the procedure of making decisions and they would actually see all of the things that are involved behind even creating a building or something, or a bridge, or all of the disciplines involved so that increases awareness and appreciation."

Examining the potential risks by demographic information showed few differences between the two institutions or between URM and non-URM participants. A larger percentage of the female participants discussed the risk of dealing with disappointed or angry members of the public (53%) compared to male participants (25%). A larger percentage of first-year students (50%) talked about the risks associated with there being too many voices in the decision-making process compared to senior students (20%), faculty (20%) and professionals (33%). Faculty participants more often cited risks of dealing with disappointed or angry members of the public (faculty - 70%, first-year – 43%, senior – 20%, professionals – 11%) or of being misunderstood (faculty - 60%, first-year – 7%, senior – 10%, professionals – 11%) compared to the others groups. Similarly, a larger percentage of the LTS participants than non-LTS participants discussed the risk of being misunderstood (26% vs. 12%) and of work being hampered (67% vs. 33%).

Looking at the benefits, overwhelmingly participants responded that they believed greater collaboration between engineers and "the public" and having more informed engineers and

members of the public would ultimately lead to better engineering decisions, better products and better solutions (n=29). A higher percentage of first-year participants (57%) talked about fostering more informed engineers as a benefit of the ideal relationship than senior (30%), faculty (40%), or professional (11%) participants. Code frequencies for all other demographic groups were similar with respect to the benefits of the ideal relationship between engineers and the public.

Discussion

Collectively, the data from these 43 interviews expresses a complex and oftentimes conflicting landscape of the engineers' social imaginary with respect to "the public." The majority of the participants included themselves and engineers in general as member of "the public," some even talked about wearing two different hats – one hat as an engineer and another as a member of "the public." Despite engineers being members of "the public", participants typically give different characterizations of engineers and "the public." Common characterizations of engineers included engineers as arrogant, objective, rational, lacking communication skills or too narrowly focused on technical issues. "The public" was characterized as contributing important experiential knowledge and knowledge of their needs and wants, while also lacking information about engineering, lacking education or knowledge in general, as technologically illiterate, emotional, illogical and as making unformed or short-sited decisions. One participant talked about this duality within himself, saying "…when you're at home, you're the public, and when you go to work, you're on active duty… When you're at work, you're a problem solver and at home you can be a problem maker."

Engineers' social imaginary is, in part, a way to differentiate between engineers and "the public." While these engineers see themselves as a part of "the public," the characteristics of "the public" were very rarely attributed to engineers in their professional role. None of the participants called engineers emotional or irrational. Similarly, "the public" was rarely characterized as objective or rational. For those participants who talked directly about sharing two hats, setting seemed to be a key element defining an individual as an engineer (at work) or a member of "the public" (at home); personality attributes or skills also seemed to change from one setting or role to the other. In thinking about this boundary as defined by characteristics and the idea of social imaginaries as an examination of boundaries and boundary crossing, it brings up key questions as to how engineers who behave irrational or emotionally fit within the social imaginary? Conversely, how do rational, objective and logical members of "the public" fit into the imaginary?

The roles of engineers and "the public" that emerged from these interviews also help highlight the social imaginaries that engineers hold of "the public." As was seen in the content analysis of foundational documents in engineering in the first part of this study [10], the engineering participants largely talked about the role of engineers in society as benefitting society, providing key goods and products and as "mak[ing] everybody's life better." The role of "the public" was largely to provide contextualized information, identify their needs and wants, and to provide a check, oftentimes in the form of product feedback, on engineers' design.

The ways in which engineers and members of "the public" should interact was also a key element of the social imaginary which emerged from these interviews. In the ideal situation, the relationship should be collaborative, with strong communication and where both parties are well informed. The benefits of this type of relationship were seen as producing better engineering products, greater satisfaction and more informed engineers and members of the public. The risks

were described as decreased efficiency, slower processes and dealing with possibly angry or disappointed members of the public with unrealistic or impractical expectations.

While most participants could characterize an ideal relationship, they struggled to define the limits of public involvement ("how far is too far"). Most wrestled with that boundary between the necessity of the technical expertise of the engineer, a strong desire for efficient solutions versus a desire for collaboration, inclusion, multiple voices and the acknowledgment that the contextualized knowledge that members of "the public" have is crucial toward finding appropriate solutions. A tension was seen in some participants' reluctance to not let the engineer have the final say. One participant's response exemplified this conflict:

> "Well the public, you know, they're not gonna, they're not gonna get into the technical details, right? I think the ultimate decision should be made by the engineers. Course, that decision should be informed by the public and the public communicate this to the engineers - what their priorities or preferences are. So perhaps that's an example. If we look at a new bridge construction, right, there's probably several different routes that the bridge could go or there's several different designs that could take on and the public maybe should inform the engineers why they think one location might be better. Or what if they prefer one style of bridge versus another - could be aesthetics. It could be capacity, there could be some safety concerns and if those are well articulated then… I think that engineer should be able to come up with the design or perhaps a small number designs and say 'this is what the options are' realistically taking into account all constraints including the budget and so forth and physics [laughs] you know 'these are the options.' So maybe that's not the final say, but certainly it needs to pass through engineering judgment on what the feasible set of solutions is…If the public is ultimately paying for it, like a bridge, then the public should have their decision on how to best spend the money but it has to be done within the confines of physics will allow, for example."

In this example, the participant starts with saying "the ultimate decision should be made by the engineers" but then, while working through the example, turns around to say that "if the public is ultimately paying for it, like a bridge, then the public should have their decision." Throughout this quote the technical expertise of the engineer is used as a fall back justification for authority ("within the confines of physics") as a key distinction between engineers and "the public." As this participant struggles with how to divide power in this relationship, negotiating the boundary between engineers and "the public," they fall back to what seems to be a prevalent principle of the social imaginary which says that engineers' authority is rooted in their technical expertise and "the public" is prone to making irrational or unrealistic requests.

One element of this study was to examine how much the social imaginaries that emerged from these interview participants varied based on cultural context or demographic background. It was hypothesized, going into this work, that institutional culture may influence the ways in which the social imaginary was expressed, but there was no clear trend to support this. The codes with the largest variation between the two institutions were identification of "the public" as clients (Large Public U – 75% vs. Small Private U – 11%), as those affected by engineering work (Large Public U – 45% vs. Small Private U – 11%) and characterizations of "the public" as lacking knowledge or education (Large Public U – 15% vs. Small Private U – 50%) or as emotional, illogical or that

they make uniformed decisions (Large Public U – 40% vs. Small Private U – 11%). Additionally, reflecting on sub-optimal communication as a common negative experience with "the public" was more common at Large Public U than Small Private U (58% vs. 22%). Neither context seemed to foster an imaginary of "the public" which leaned more heavily toward one characteristic or another, nor did participants from one institution refer to educational experiences overwhelmingly with a higher frequency than the other. The largest difference was the use of the term "client" at Large Public U, which could simply reflect language differences in the institutional culture between the two schools. The two educational experiences with the largest institutional differences were general statements about school fostering an awareness of engineers' service to "the public" and the use of codes of ethics, both with higher response rates from Large Public U than Small Private U.

Examining the largest differences in code prevalence by gender showed that female participants were more likely than male participants to point to interactions as practicing engineers as being influential to their views of "the public" (53% vs. 25%), but also that their education was silent about "the public" (58% vs. 33%). They were more likely to describe the ideal relationship as a forum to exchange information (47% vs. 21%), and with the risk of dealing with disappointed or angry members of "the public" (53% vs. 25%). Further work is needed to more deeply examine these differences and, perhaps drawing from other studies on gender differences within engineering, to showcase in what ways gender may influence the social imaginary.

The largest differences between URM and non-URM participants were for the characterization of the public's asset as knowing their own priorities and needs (URM – 75% vs. non-URM – 39%) and describing interactions as practicing engineers as being influential to their views (URM – 58% vs. non-URM – 29%). Non-URM participants were more likely to describe the public in ways that excluded engineers (26% vs. 0%) and to talk about the need for engineers to listen to the public when describing the ideal relationship (42% vs. 17%).

The largest differences between LTS and non-LTS participants included a larger percentage of LTS participants had interacted with the public as engineers (71% vs. 21%) and that LTS participants were more likely to talk about the risk of being misunderstood, misquoted or misrepresented in the ideal relationship (56% vs. 12%) or that work may be hampered (78% vs. 39%). These may come directly from LTS experiences, where engineers, usually without any formal training, interact with non-engineers on service projects. This can create an environment where students (and faculty) are negotiating the pull between academic culture and "the real world." Students can be thinking largely with a school mindset, focused on tasks, deadlines and the academic calendar. This can conflict with partnerships in non-profits or community groups that function on different timelines. Non-LTS participants were more likely to describe engineers' role in society as creating the conditions needed for the public to thrive (48% vs. 0%). These sorts of broad statement may characterize an overinflated sense of impact that non-LTS participants may hold and that LTS experiences may temper in students and faculty who engage in these types of service projects.

Many of the large differences among code prevalence for participants based on their position (first-year undergraduate students, senior undergraduate student, faculty or professional) were expected, usually with first-year students having little or no experience compared to the other groups. Examining the differences between first-year and senior students, with the idea that trends could represent changes that occur during one's undergraduate education, showed that

more senior participants identified "the public" as those who are affected by engineers' work (70% vs. 21%) and to see the publics' knowledge of their needs and priorities as an asset (70% vs. 29%). First-year students were more likely to characterize "the public" as lacking information (43% vs. 0%) or as being emotional, illogical or making uniformed decisions (36% vs 0%). The codes with the largest differences point to a shift in student thinking over their undergraduate education toward a broader consideration of who "the public" is, how engineering impacts "the public" and what assets "the public" may contribute to engineering work. The codes which were common among first-year student but less common among senior students appear more simplistic and to follow stereotypes of "the public" compared to engineers, whereas senior student's views hold more nuance and complexity.

One of the largest differences between the engineering faculty participants and professional engineers was the characterization of the ideal relationship between engineers and "the public" as collaborative, bidirectional or culturally appropriate, which all of the faculty mentioned and only three of the nine professionals discussed. Perhaps the practicing engineers drew more from their experiences executing engineering projects when discussing the ideal relationship, which, when the public is included, can be messy, whereas faculty may be drawing from a more theoretical view of engineering practice when answering this question. Collaboration may be something that is easy to talk about in theory, but very difficult to achieve in practice, also contributing to these differences. Potential misalignment between academia and professional practice is one area that future work should look at with respect to messages about "the public" and lessons about the relationship between engineers and "the public."

Limitations

The main limitation of this study is that participants were selected from two institutions (with the exception of some of the professional engineers) and therefore may represent similar educational exposure to messages around "the public." Constructive or destructive messages could be overrepresented in either population if a common course or department held atypical views and infused those into their courses. Response bias is always a concern with interviews, where "socially acceptable" answers may be more likely to be given by participants if they do not feel comfortable sharing more extreme or fringe views in the context of the interview or with the researchers.

Conclusions

This exploratory analysis of the social imaginaries of engineers with respect to "the public", as seen through interviews with engineering students, faculty, and professionals, has highlighted some of the expected characteristics, roles, and boundaries associated with both groups. Generally, "the public" was identified as everyone, including engineers, and also by their relationship to engineers' work as clients, consumers, customers or users. Assets or strengths of "the public" included their experiential knowledge and an understanding of what their needs/wants are. Deficits of "the public" included a lack of information about engineering, generally, or about technology, being irrational or emotional, having unrealistic expectations or making uninformed or short-sighted decisions.

Most participants pointed to general life experiences as being most influential to their views of "the public" rather than their education. About half pointed to messages around safety, service, or ethics in their engineering education as being influential to their views of "the public" while

the other half talked about how messages were explicitly absent from their engineering education. A few participants reference negative messages that they received about "the public" in their engineering education. Positive interactions with "the public" revolved around feeling like they benefitted the public and were appreciated, while negative experiences revolved around interacting with angry or disappointed members of "the public" or poor communication on the project.

Overwhelmingly the view of the engineers' role in society was as benefitting society and the role of "the public" was to help define the issues that engineers should work on and to give feedback to engineers as a check to make sure their work is relevant. The ideal relationship was characterized most often by improved collaboration and communication, where both engineers and "the public" gain a better understanding of each other's' views and needs. The benefits of this ideal relationship were characterized by better engineering solutions and better communication, but the risks included a loss of efficiency and the potential of dealing with angry or disappointed members of "the public." The ideal, however, was often not seen as the current reality which was characterized as having a strong disconnect between engineers and "the public" with sub-optimal communication and where engineers don't listen to "the public."

Together, these elements help us to better understand the engineers' social imaginary with respect to "the public" including the boundaries that identify and separate the two groups and the roles of each with respect to the other. Understanding the ways in which engineers envision "the public" can also help us to examine engineering failures through a different lens, one which focuses not on the specific choices of the individual, but instead on the systemic passing on of conceptions of "the public" in engineering that may paint "the public" as a hinderance to engineering efficiency and where engagement with "the public" is seen predominately as more of a risk than an opportunity. More work is needed to further examine how these social imaginaries are passed on in the training of engineers, consciously and subconsciously, in engineering education and professional practice. This may highlight ways in which the engineering education community can intentionally change the imaginary toward the ideal that many participants talked about which was collaborative, mutually respectful, and where both engineers and "the public" are informed and benefit.

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Appendix - Interview Questions[1]:

- Give me a brief history of your engineering career.
    - *What are/were your motivations for choosing engineering?*
- Thinking broadly, who is the public and how would you characterize the public?
    - What knowledge or capacities does the public hold that might be relevant to engineering?
    - What experiences have shaped your views of the public?
    - How has your education shaped your views?
    - What deficits does the public have with respect to engineering?
- Have you ever had any experience interacting with the public as an engineer?
    - If yes, describe an experience that was good. One that was bad.
- What is the role of engineering in society? How do engineers affect society?
- What is the role of the public in engineering decision making?
    - *To what extent should the public have a voice in engineering decision making?*
    - *At which stages of the engineering design process?*
    - *How far is too far for public involvement? Give an example.*
- In thinking about interactions between engineers and the public, how would you characterize the ideal relationship?
    - In what ways is this different from the current reality, as you understand it?
    - What are appropriate points of contact between engineers and the public?
    - What are the potential risks of this interaction between engineers and the public?
    - What are the potential benefits?

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- *What is your reaction to the article? How are you processing this?*
    - *What should be the next steps?*

- *Can you think of any instances where engineers may have caused harm to the public?*
- *Some professional societies have collectively spoken out against specific social issues, such as the APA against torture and the American Institute of Architects against capital punishment. Can you think of any issue where it might be appropriate for an engineering professional society to speak out against in a similar manner?*

- *How would you define "Social Responsibility"?*
    - *How might "Social Responsibility" be applicable to engineering?*
- *How would you define "Social Justice"?*
    - *How might "Social Justice" be applicable to engineering?*
- *How would you define "Activism"?*
    - *How might "Activism" be applicable to engineering?*
- *How would you define "Citizen Science"?*
    - *How might "Citizen Science" be applicable to engineering?*

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[1] Responses to questions noted in italics were omitted from the analysis presented in this paper