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Really Changing the Conversation: The Deficit Model and Public Understanding of Engineering

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Introduction

Numerous reports and outreach initiatives stem from a concern over low public understanding of and interest in engineering. Most often, these reports and initiatives express a belief (either implicitly or explicitly) that the public does not understand or appreciate engineering because they are uninformed or misinformed and that, consequently, the provision of more information (in the form of scientific literacy or the benefits of engineering) will lead to increased understanding and support for engineering. In that way, such initiatives are enactments of the deficit model. The deficit model (DM) is a term from the field of Science and Technology Studies (STS) used to describe initiatives/projects that are based upon a belief in the public's lack of knowledge and scientific literacy and seek to remedy it by providing more, and correct, information. However, a large body of literature has now identified significant problems with the deficit model, including problems that undermine the aims of organizers or authors, thus limiting efficacy of efforts to communicate with the public. Therefore, the aim of this paper is three-fold: 1) to introduce the deficit model to an engineering education audience, 2) to identify leading critiques that engineering educators and students should be aware of, and 3) to present a framework that can be used by engineering educators and taught to future practicing engineers to think through important dimensions of communication.

The paper begins with an introduction to the deficit model. We explain the concept, identify its major limitations, and briefly discuss alternative communication models. Following that is a discussion of three dimensions of science and engineering communication. We then present our findings on the ways in which the deficit model has recently been enacted in engineering communication contexts. Next, we present a framework of key concepts integral to public communication so that engineers can reflect upon how these dimensions affect the ways communication with the public is carried out. The paper concludes with a discussion of significance, intersecting issues, and future work.

Overview of the Deficit Model

The *deficit model*, a term originally coined by science studies scholar Brian Wynne,[1] refers to approaches to science and engineering (S&E) communication and outreach that are based on the belief that publics are critical or skeptical of, and not interested in, S&E because they do not have enough information or are misinformed.[2,3] Since the 1980s, S&E communication has been dominantly geared towards educating a public perceived as misinformed and/or having a deficit of knowledge.[2,4] Within these deficit model initiatives, the solution to increasing public interest in and support for S&E is to provide them with more information about science and engineering, including its benefits to society. As Bucchi & Neresini[4] explain:

> This model has emphasized the public's inability to understand and appreciate the achievements of science—owing to prejudicial public hostility as well as to misrepresentation by the mass media—and adopted a linear, pedagogical and paternalistic view of communication to argue that the quantity and quality of the public communication of science should be improved. (p. 450)

In addition to the deficit model approach being the dominant science communication approach, it can also be seen in many public understanding of engineering (PUE) communication initiatives.

Critiques of the Deficit Model

Numerous critiques have been levied against the deficit model, and the assumptions upon which it rests.[2,4-6] First, it rests upon the assumption that the publics' views can be changed and that the way to do so is to increase "scientific literacy" with more information. Once scientific literacy increases, it is assumed, a positive attitude toward science and technology will inevitably follow.[4] However, these assumptions do not hold up when considered in light of studies challenging the connection between "exposure to science in the media, level of knowledge, and a favorable attitude toward research and its applications" (p. 450).[4] For instance, research has shown that the most informed members of the public also have a "substantial degree of skepticism and suspicion" toward biotechnologies (p. 450).[4]

A second critique of the deficit model is that it disregards "lay" knowledge, or publics' knowledge about S&E in their lives. Expertise is conceptualized in narrow terms as something acquired only through formal education in S&E. It is important to problematize what is meant by "understanding".[5] By equating "public understanding of science" with scientific literacy, or "the ability to understand science 'correctly' as it is communicated by the experts, which is measured by appropriate questions on scientific methods and contents" (p. 450),[4] the deficit model obscures the many other ways in which publics can legitimately understand science, including critical social perspectives. In other words, it elides knowledge of scientific facts with knowledge of how science and technology operate in people's lives and excludes the latter. Such elision is problematic because numerous studies demonstrate that publics often have very sophisticated understandings of science and technology in ways that scientists and engineers do not, often rooted in their own local and lived experiences. As Bucchi & Neresini[4] state:

> [T]he disjunction between expert and lay knowledge cannot be reduced to a mere information gap between experts and the general public as envisaged by the deficit model. Lay knowledge is not an impoverished or quantitatively inferior version of expert knowledge; it is qualitatively different. Factual information is only one ingredient of lay knowledge… (p. 451).

For example, following the Chernobyl nuclear disaster, sheep farmers in the United Kingdom had more accurate knowledge of radiation in the area than the scientific experts.[1, 7-9] Another example can be found in the work of Steve Epstein who explores the role of lay knowledge in AIDS research.[10]

A third, related critique is that the deficit model tacitly privileges one epistemology (belief about the nature of knowledge) over others.[2,11] The dominance of the deficit model has been attributed to scientists' beliefs about the nature of science. As Tanona and colleagues[11] argue:

> Analysis of the norms that scientists hold regarding their communication with the public indicates that there are several core values many of them hold, including objectivity, accuracy, and lack of bias. It is plausible that these norms influence scientists' choice of communication strategies. (p. 29)

In other words, the positivism characteristic of modern science has also shaped the strategies used to communicate about science. Because the social, cultural, and political dimensions of science and engineering are not widely discussed, there seems to be no need to take lay knowledge into consideration or engage with critiques. This is problematic, however, because science and engineering are not value-free or unbiased enterprises.[12] Indeed, the field of STS is built upon countless studies documenting that science and engineering are not value-free or objective in the ways that they are commonly believed to be.[13-20] This body of literature has demonstrated that values and biases shape S&E in multiple ways, including the questions that are asked and researched, the ways data and observations are interpreted, the interests that are served, the technologies that are produced and the ways they are designed.

Alternatives to the Deficit Model

Alternatives to deficit model exist and have been widely discussed in fields such as STS, if not yet in engineering education. The goal of this paper is not to provide an in-depth synopsis of all such models, but rather to introduce a framework from which to better understand the characteristics of communication models. Other scholars have described numerous alternatives in greater detail. Well-known examples include: science shops,[21,22] public hearings, citizen juries, consensus conferences, consultative panels, stakeholder consultations, and focus groups.[4,6,23] Generally, these models differ from the deficit model in that they aim for some form of democratic public participation in S&E decision-making processes beyond opinion polls or surveys. However, it is important to note that even many alternative models have been critiqued for limitations of their own.[4,23]

Examples of public participation in engineering projects specifically include the Keystone XL project,[24] the Fernald Citizens Advisory Board (FCAB),[25] and the Pebble Project.[26] Each of these projects sought to include public stakeholders through public advisory committees or public hearings. We return to these examples below after discussing dimensions of S&E communication and how different types of publics are constructed through certain S&E communication models.

Dimensions of S&E Communication

Direction of Information and Level of Influence

The features of the deficit model identified in its critiques lead to a narrow range of S&E communication activities. Scholars who have studied S&E communication have identified several dimensions along which communication can be conceptualized. In the deficit model, because it is publics who are the problem and need to change while S&E communities are left unproblematized or unchallenged,[4] communication is limited in several key dimensions, including the direction information flows and the intended level of influence, or expectation for change.

Information flows can be one-way (monologic), or two-way (dialogic).[11] Another dimension of communication is the expectation of change vis-à-vis the participants involved (hereafter referred to as "level of influence." In asymmetric communication, only one party is expected to change, whereas in symmetric communication, both parties are open to change.[11] The lowest levels of communication are one-way flows, where the party receiving information is the only party expected to change its views; on the other hand, dialogic and symmetric levels of communication are understood as higher forms of communication because they are more "democratic," facilitating more participatory communication for publics.[6] The deficit model is characterized by monologic and asymmetric communication,[2] as depicted in Figure 1 below. The monologic and asymmetric characteristics of the deficit model mean that there is no space in that model for publics to challenge normative or dominant beliefs.

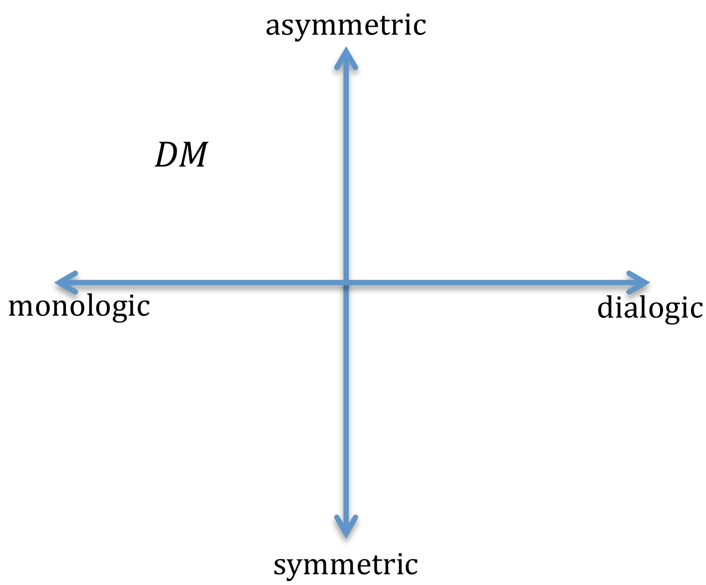

Figure 1. Spectrums of information flow and intended influence

Type of Public Engaged

In this analysis, we draw on Braun and Shultz's typology of publics.[23] While their typology was developed in the context of participatory governance for genetic testing in the United Kingdom and Germany in the 1990s and 2000s, we find the typology useful to frame our discussion of the deficit model in engineering contexts. They delineated four types of publics (based upon the work of Reynolds et al.[27]), which are summarized in Table 1 below: the *general public*, the *pure public*, the *affected public*, and the *partisan public*. They use the concept of the "construction of publics" to illustrate how various "speaking positions" have been constructed through public participation in S&E and used to portray public knowledge as ultimately right or wrong.

Table 1: Overview of different publics

Public	Description	Potential to challenge normative/dominant positions	Mechanisms of engagement in deficit model
General	Aggregate of individuals' views representing large segment of the population	Weak	Opinion polls, surveys, and reports
Pure	Has no preconceived opinion	None	Outreach initiatives and reports
Affected	Has strong views molded through personal experiences	Strong	None
Partisan	Organizations/groups that hold collective opinions	Strong	None

The general public is a type of public in which the average of all views concerning a certain topic becomes representative of everyone.[23] Views that are widely held amongst the majority of individuals come to represent the view of the general public because the pooling together of opinions dilutes deviating views between individuals. Pooled together, the viewpoints center between extremes, hiding the deviation of views. Therefore, the general public construction masks the views of those who do not align with general opinion. The primary purpose of polling the general public has been to provide information to various governmental and non-governmental organizations, leading Braun & Schultz to label them "technologies of elicitation" (p. 408).[23]

The pure public, on the other hand, is a segment of the general public characterized by lack of knowledge and/or lack of strong conviction about a given topic. The pure public's perceived lack of knowledge lends itself to a viewpoint that is more malleable to other alternative views for two reasons related to perceived lack of knowledge. First, the pure public's perceived lack of knowledge allows it to be viewed as more impressionable than other types of publics. Second, its perceived lack of knowledge diminishes its ability to challenge normative positions and weakens the authority of recommendations it might provide. As a result, pure publics are often invited to events designed to educate and change views, which, in contrast to "technologies of elicitation," are referred to as "technologies of transformation" (p. 409).[23]

Unlike the pure public, the affected public consists of individuals having strong views molded through actual experience with the topic at hand.[23] The possession of experiential knowledge allows the affected public to potentially have a strong speaking position when placed alongside experts; however, this can only occur if the communication event is set up to value such knowledge.

Finally, the partisan public consists of organizations that have collective opinions about a science or engineering issue.[23] The collective or group nature of the partisan public is what distinguishes it from the three other types of publics whose constituents act individually. In the other publics, individuals may affiliate themselves or be educated by views of other groups, but their participation remains individual. The partisan public is also characterized by a strong speaking position due to its organized nature, often having the resources of lobbies or political parties.

In the deficit model, only general and pure publics are engaged. There is no mechanism for specifically engaging affected or partisan publics. This is a problem for several reasons. First, because both the general and pure publics are perceived to have inaccurate and/or limited engineering knowledge, they cannot challenge normative or dominant narratives about engineering. Secondly, the knowledge of affected and partisan publics, which *can* introduce important critiques, is not heard. It is important to engage affected and partisan publics because the first-hand experience and strong speaking positions they possess allow for different types of conversations about engineering, including the introduction of critique. Both the affected and partisan publics have the potential to re-balance the level of influence and the flow of information that has been traditionally dictated by experts, ultimately allowing for different narratives about engineering to be heard.

In contrast to the DM, the engineering projects identified above have engaged partisan and pure publics and also employed dialogic and symmetric communication. For instance, the Fernald Citizen's Advisory Board (FCAB) was originally convened in August 1993 to address the demands of citizens about contamination created by a DOE (Department of Energy) facility in Fernald, Ohio.[25] A board of labor spokespersons, community government agents, officers from a local environmental activist group, scholars, and local industry was responsible for providing guidance to the DOE, US Environmental Protection Agency (EPA), and the Ohio EPA with consideration to the future of the Fernald site, residual risk and remediation levels, waste disposal location, and priorities among remedial actions.[25] FCAB, which is similar to what Rowe & Frewer[6] label *public advisory committees,* included an affected public whose health and environment were at risk from the Fernald site and who were able to communicate with the DOE through regular meetings with the important ability to sway the DOE's final decision-making through a dialogic and symmetric process. Another example is found in the Pebble Project in which the EPA held public hearings in 2012 in order to determine both the fate of the largest sockeye salmon fishery in North America and a proposed open pit mine, called the Pebble Project, that would be the largest ever constructed.[26] The Pebble Project hearings are noteworthy primarily in how the design of the two hearings integrated two opposing partisan publics (those for and against the project) into the discussion. It is not clear whether the EPA intentionally designed the hearings to accommodate for the two competing partisan voices behind the Pebble Project; nevertheless, the hearings effectively allowed a partisan public to voice their opinions in a symmetric and dialogic conversation about the potential effects of an engineering project. These examples demonstrate that there is a range of communication models that can serve different purposes and produce different outcomes through the types of publics they engage, the direction of information flow, and intended level of influence. We turn now to our findings of the ways in which the deficit model has been prominently enacted in engineering contexts, largely limiting engagement to general and pure publics through monologic and asymmetric communication.

Recent Enactments of the Deficit Model in Engineering Contexts

The deficit model is routinely enacted in engineering (education) contexts. One such initiative was the national rebranding campaign for engineering entitled *Changing the Conversation*

(CtC).[28] We focus on CtC because it is a prominent, well-known recent example representative of national communication efforts. The report argued that lack of public understanding of engineering was detrimental in several different ways. First, it diminishes public appreciation of the achievements of engineering:

> [T]he 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… And when the relative prestige of all professions is tallied, engineering falls in the middle of the pack, well below medicine, nursing, science, and teaching. (p. 17 – 18)

Second, it impairs the public's technological literacy:

> Some knowledge about how engineering work is done, for example, is fundamental to technological literacy. To be fully capable and confident in a technology-dependent society, every citizen should understand something of the process of engineering and how engineering and science, among other factors, lead to the development of technologies. (p. 18 – 19)

Third, it decreases the public's ability to perform civic duties:

> A number of important public policy issues, from global warming to the marketing of genetically modified foods, involve scientific and technical issues. Decision making on these and other topics will involve trade-offs, as we attempt to simultaneously manage limited resources while sustaining quality of life. Public discourse and the democratic process could be enhanced if citizens understood more about how engineers are trained and what the practice of engineering entails. (p. 19)

Fourth, it reduces the public's ability to support technological innovation:

> Improved public understanding of engineering may also support U.S. efforts to maintain our capacity for technological innovation, an issue that has received considerable attention recently. Effective action…will depend partly on how well policy makers and the public understand what engineering is and how it contributes to economic development, quality of life, national security, and health—information that could be conveyed through effective messaging. (p. 19-20)

Fifth, it limits the size of the engineering labor market:

> Women, African Americans, Hispanics, Native Americans, and some Asian American groups are significantly underrepresented in engineering, based on their proportions in the population at large…In the future…the engineering profession will have to draw more heavily on underrepresented groups for the country to maintain, let alone increase, its technological capability. Thus messages that effectively encourage girls and underrepresented minorities to consider careers in engineering could be crucial to U.S. success and leadership in the future. (p. 21)

These motivations for the CtC campaign indicated that lack of public understanding of engineering (PUE) was affecting the public's ability to fully benefit from engineers' work. The NAE concluded that more information about engineering was the solution.

Another initiative that enacted the deficit model was the National Science Foundation's report entitled "Making the Case for Engineering" (MCE).[29] The MCE report aimed to find ways to increase public support of engineering and concluded that improving PUE was necessary for similar reasons as the CtC. First, the lack of PUE affects the public's ability to fully appreciate the achievements of engineering:

> As noted here, engineers, even during a time of rapid technological advance and improvements in our standard of living, have not been perceived more prestigiously. Part of that lack of change may in fact be due to broad misconceptions by the public as to what engineering is, what engineers do, and how engineers contribute to society. (p. 14)

Second, it diminished the public's technological literacy:

> Other studies indicate that most Americans are probably not technologically literate. They have little conception of how science, technology, and engineering are related to one another, and they do not clearly understand what engineers do and how engineers and scientists work together to create technology. (p. 15 – 16)

Third, it caused the public to define engineering incorrectly:

> In the ITEA survey, respondents were asked to name the first word that comes to mind when they hear the word "technology." Approximately two-thirds said "computers." Moreover, when given a choice of two definitions for "technology," 63 percent chose "computers and the Internet," whereas 36 percent chose "changing the natural world to satisfy our needs."… A majority of survey respondents (59 percent) associated the word design (in relation to technology) with "blueprints and drawings from which you construct something" rather than "a creative process for solving problems." (p. 16)

Like CtC, the MCE report listed lack of PUE as the main reason for insufficient public support. It again called for messaging that will improve public understanding of engineering to garner greater public support for engineering that could translate into greater engineering related research funding, greater diversity in the workforce, and ultimately a greater ability to innovate among other things.[29] Both the MCE and CtC, as well as many other examples such as Engineers Week initiatives, ultimately aimed to bring the public in closer contact with engineering. However many scholars argue that the DM approach undermines such efforts.

In addition to these published reports, recent research shows that engineers and engineering students enact the deficit model in the course of their work.[30,31] Two examples can be drawn from synthetic biology, which vies to be an emerging engineering field. While describing their observations of a synthetic biology competition for undergraduates, Frow & Calvert[30] note that the students' approach to addressing the social facets of their engineering projects:

> …effectively divorces 'the social' from 'the technical,' positioning Human Practices work downstream of the research being done. Many teams adopt a standard "deficit model" approach and devise activities to educate and enthuse members of the lay public

> about synthetic biology. Surveys (often of poor quality) are also frequently used to try and identify public attitudes towards synthetic biology. (p. forthcoming)

Similarly, an ethnographic study of practicing synthetic biologists in the UK revealed engineers and scientists defaulted to framing perceived barriers to innovation in terms of public lack of understanding. Balmer & Molyneux-Hodgson[31] explain that:

> In our ethnographic work more nationally, attending the events organised by government, research groups and funders, in meeting after meeting, conference after conference, the same assumptions about public ignorance of synthetic biology were re-hashed… Indeed, this is an exceptionally obstinate position, in which non-scientist actors are positioned as simply adopting opinions on science that are spoon-fed by pressure groups or lazy journalists. The understanding of our synthetic biologist colleagues thus seems to be that there is simply one correct account of bacteria in synthetic biology, the scientific/engineering one, and that others represent distortions and misunderstandings… In the process of problematizing the uptake of synthetic biology, our engineering colleagues both local and national adopted ignorance as the central concern…The response to such a problematization is, for synthetic biologists, to educate through engagement and to appeal to regulators for understanding. (pp. forthcoming)

These recent examples demonstrate that the deficit model persists prominently in engineering and engineering education contexts. Thus, engineering educators have opportunities to discuss the deficit model with students in ways that very directly relate to their own work, in addition to through the use of national reports. During such discussions, it may be useful to have a framework for thinking through the multiple dimensions of communication that can shape any such effort. Below, we present one such framework.

A Framework for Thinking about Public Communication of Engineering

The three dimensions of S&E communication discussed above are related to the goals organizers have for any given event or program. Figure 2 presents a framework that combines these elements. Figures 3 and 4 show that these dimensions influence the type of forum that is selected for a communication event. The framework can be used to help engineering educators and students reflect upon and plan their own communication initiatives, ideally working to overcome limitations or problems that are created when relying solely on DM communication. We intend the framework to help engineering educators and future engineers think through dimensions of their communication projects and strategically identify characteristics that align with their desired outcomes.

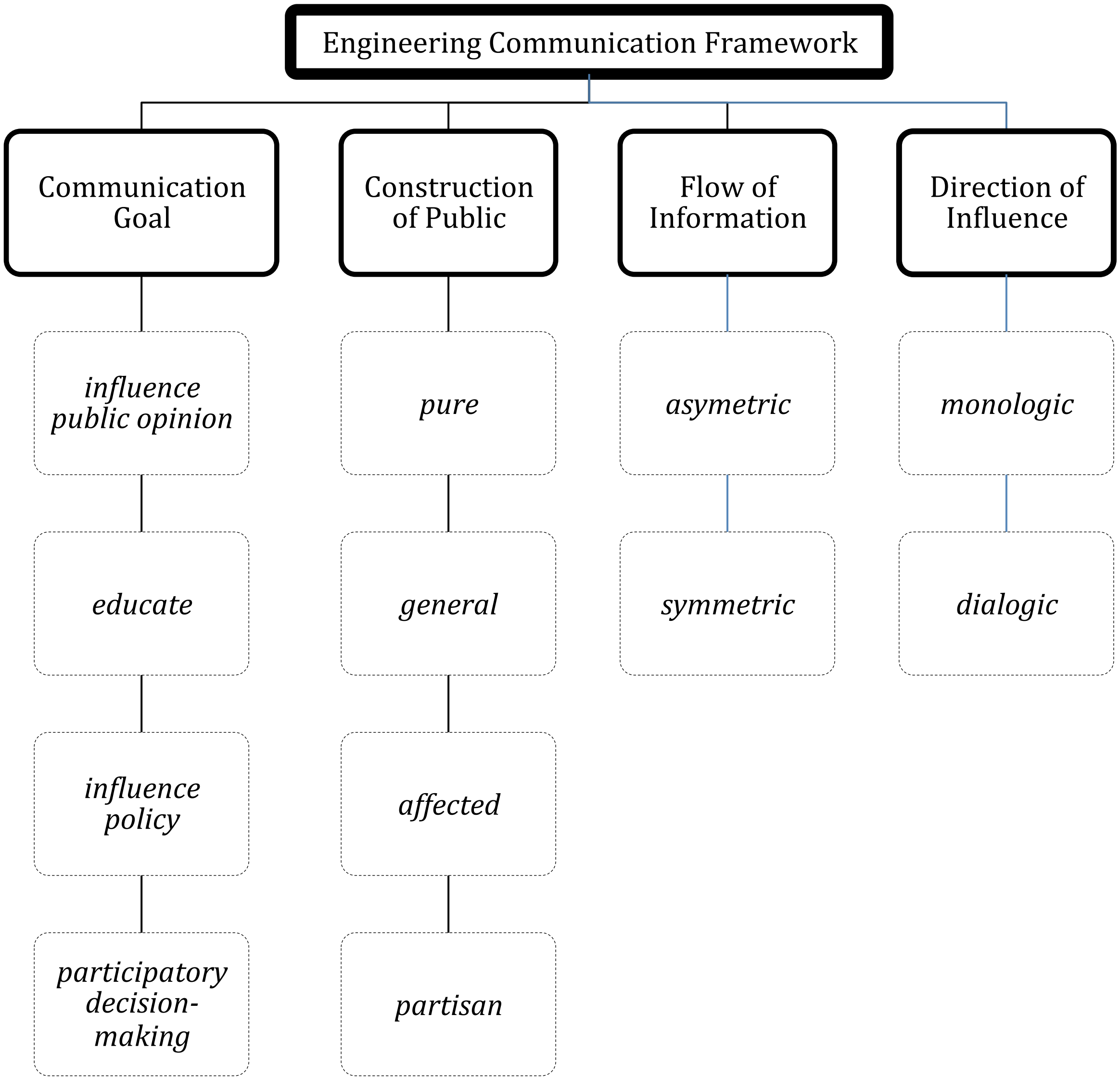

Figure 2. Dimensions of Science and Engineering Communication Framework

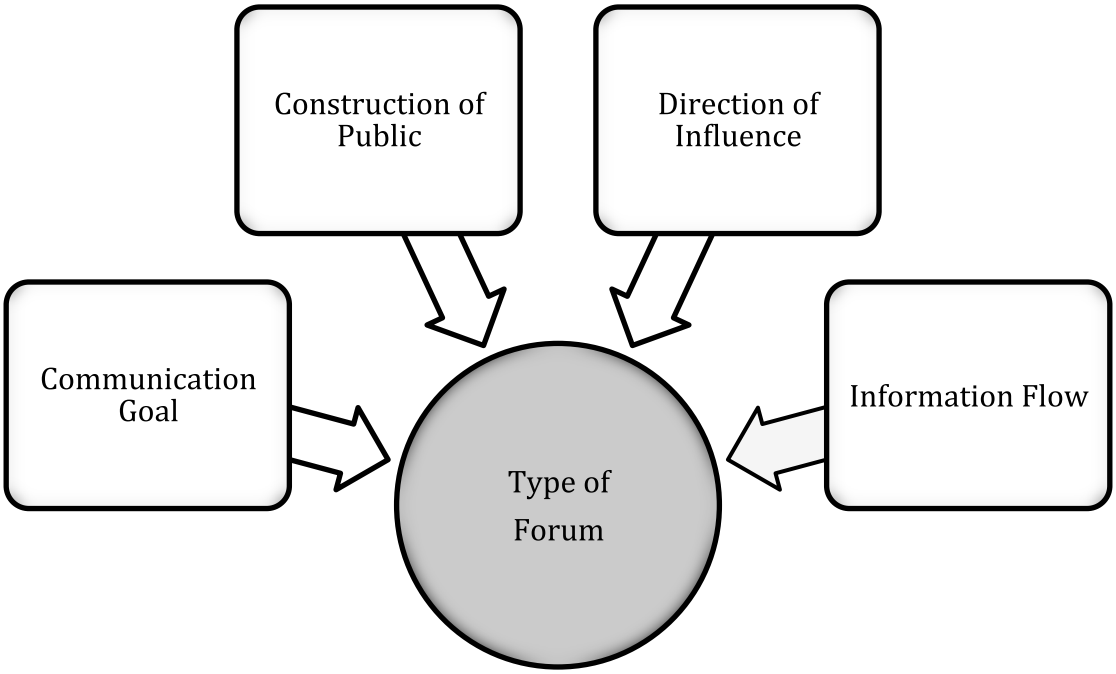

Figure 3. Factors shaping the type of forum selected

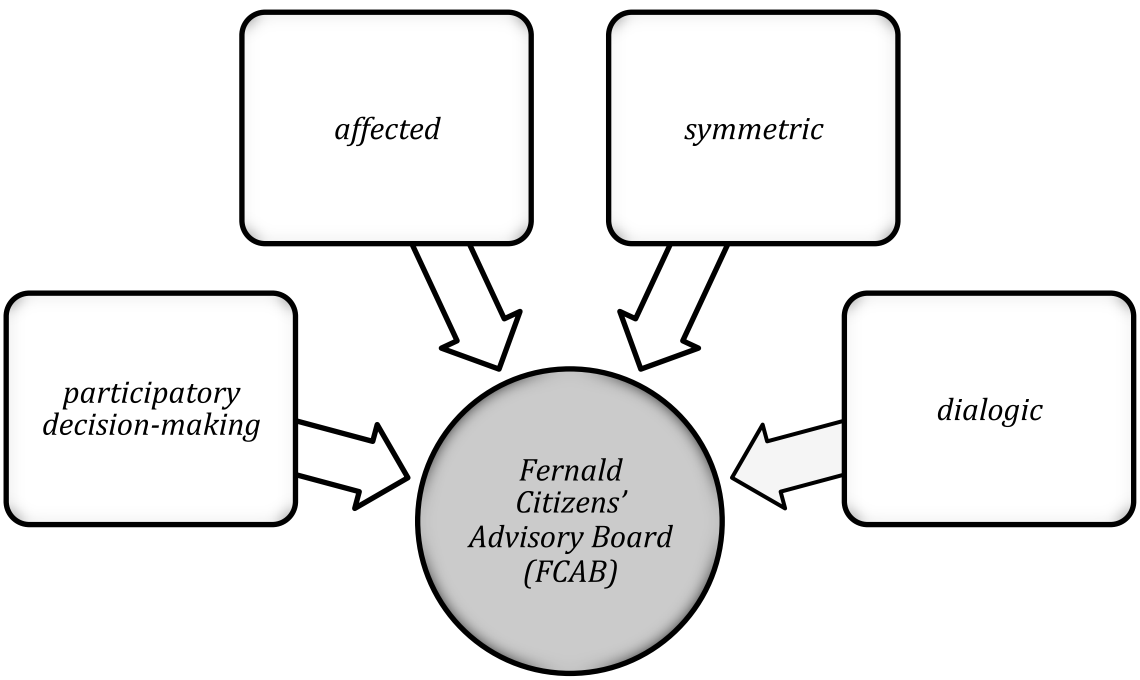

Figure 4. An example applying the framework to FCAB

Assessment of any given event or program will necessarily depend on the goals set for that initiative because the method of assessment should align with the desired outcomes. Therefore, the aim of this paper was not to specify universal assessment methods, but rather to introduce deficit model literature to an engineering education audience. However, other scholars have discussed evaluation of democratic initiatives. For example, Rowe & Frewer[6] identified criteria that should be used to evaluate public participation initiatives. They included:

- *Representativeness* (should include a "broadly representative sample" of the affected public (p. 12))
- *Independence* (participation and participants should be independent and unbiased)
- *Early involvement* (public should be involved "as early as possible…as soon as value judgments become salient" (p. 14))
- *Influence* (should have "genuine impact on policy" (p. 14))
- *Transparency* ("public can see what is going on and how decisions are being made" (p. 15))
- *Resource accessibility* (participants have access to "appropriate resources" (p. 15))
- *Task definition* ("nature and scope of participation task should be clearly defined" (p. 16))
- *Structural decision-making* (should have "appropriate mechanisms for structuring and displaying the decision-making process" (p. 16))
- *Cost-effectiveness*

Although all of these criteria may not be appropriate for all initiatives, these criteria are leading features upon which an initiative aimed at influencing policy or participatory decision-making could be assessed. Methods for assessing any initiative could include interviewing participants and organizers, surveys, participant observation, and longitudinal data collection. Certainly, additional efforts and tools to assess communication events are needed, and we hope this paper prompts others to develop such tools at the same time they plan their events or programs. It is also worth recalling here that although DM initiatives are the norm, they have largely not been proven successful in meeting their desired outcomes.

Conclusions and Future Work

The deficit model persists in many engineering communication initiatives despite the numerous critiques against it. One reason for its persistence is that experts cling to the idea that information about engineering must be presented in an objective way,[11] where objectivity is understood in positivist terms. The reliance on such a presentation of information typically only permits a one-sided conversation because the public is not viewed as well-informed enough to testify alongside experts. Public knowledge is marginalized as a lack of understanding when it falls in disagreement with what engineers might want it to be. Furthermore, such models lack mechanisms to understand *why* the public might think differently about engineering, and the methods used to gather data about public understanding limit what can be communicated.[5] In adopting a model of communication that neglects to account for values, experiences, and knowledge different from their own, engineers may be undermining their own efforts.

By limiting engagement to general and pure publics, critiques of engineering can be largely ignored. Braun & Schultz identified a trend wherein public participation initiatives focus on individuals and value harmony, consensus, and education over conflict, struggle and diversity of perspectives, which is a problem because it hides issue of power.[23] They assert:

> Issues of distributive justice, research priorities, economic interests, and effects of biotechnologies on society as a whole, which would require speaking positions of social or political groups, are hard to articulate within such a framework. The tendency towards individualised, "naive" or "authentic" subject construction implies a tendency to fragment, ethicise, and depoliticize the issue at stake and to foreclose more antagonistic political contestation. (p. 416)

This paper aligns with their work in suggesting that organizers of engineering communication initiatives should consider the relationships between, on the one hand, the type of public engaged, direction of information flow, and intended level of influence, and, on the other hand, the types of conversations that are even possible.

Finally, it is worth noting ways in which the deficit model is bound up with other engineering education initiatives that have been critiqued. For example, attempts to address underrepresentation often invoke the deficit model in ways that proscribe critique, as we saw in the CtC report. As Beddoes[32] explains:

> [I]f it is thought that more women are not attracted to engineering because they simply are not aware of it or because they do not know what work engineers do, then efforts will of course focus on outreach and informing girls and women of the opportunities engineering careers offer them. However, by thinking about the problem in this way, the field itself is unexamined and unchanged because discourses that locate the causes as masculine biases within engineering itself are not considered. (p. 1118)

Therefore, the deficit model - and its limitations - have broad implications related to a range of challenges that engineering educators have identified as important. Future work will explore these connections in more depth, examining ways in which the deficit model influences diversity initiatives.

Additionally, future work will include a more in-depth critical analysis of CtC, focusing on process and recommendations, exploring how the research was conducted, how the recommendations were developed, and how various stakeholders were involved – or not – in the different stages of development. Future work will also be directed towards investigating practicing engineers' beliefs and practices related to public communication, surveying the public after participation in an engineering-related forum, and monitoring the implementation of public participation using evaluation criteria to assess its success. Findings from that research will aim to improve engineers' communication with diverse publics.

We are not suggesting that engineers should not reach out to the public. Nor are we suggesting that publics do not need access to information about engineering. Both outreach and S&E literacy efforts can be valuable, and we join others in advocating broader and deeper public engagement with science and engineering in ways that attend to their sociopolitical functioning.[e.g., 33,34] What we *are* suggesting is that the ways in which such initiatives are typically undertaken have problematic facets that limit their efficacy. Those facets should be recognized and addressed in order to move beyond the limitations, increase their efficacy, and increase engagement with lay knowledge and critical perspectives on engineering.

Acknowledgments

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