Universalized Narratives: Patterns in How Faculty Members Define "Engineering"

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BACKGROUND
U.S. engineering educators are discussing how we define engineering to ourselves and to others, such as in the recently released U.S. National Academy of Engineering (NAE) report, *Changing the Conversation*. In these conversations, leaders have proposed the skills, knowledge, processes, values, and attitudes that should define engineering. However, little attention has been paid to the daily work of engineering faculty, through their engineering research and teaching students to be new engineers, that puts these discipline-defining ideas into practice in academia.

PURPOSE (HYPOTHESIS)
The different types of narratives engineering faculty explicitly or implicitly use to describe engineering are categorized. Categorizing these common narratives can help inform the nationwide conversation about whether these are the best narratives to tell in order to attract a diverse population of future engineers.

DESIGN/METHOD
Interviews with ten engineering faculty at a research-extensive university were conducted. Interview transcripts were coded thematically through coarse then fine coding passes. The coarse codes were drawn from boundary theory; the fine codes emerged from the data.

RESULTS
Faculty members' descriptions moved within and among the narratives of engineering as applied science and math, as problem-solving, and as making things. The narratives are termed "universalized" because of their broad-sweeping discursive application within and across participants' interviews.

CONCLUSIONS
These narratives drawn from academic engineers' practice put engineering at odds with recommendations from the NAE report. However, naming the narratives helps make them visible so we may then develop and practice telling contrasting narratives to future and current engineering students.

KEYWORDS
discourse analysis, engineering epistemology, faculty work

I. INTRODUCTION

In the summer of 2008, the National Academy of Engineering published a new report, *Changing the Conversation*, which argues that engineers (and particularly engineering educators) should change the message of engineering away from the difficulty and elite character of the profession towards one of social relevance and "making a difference" (Committee on Public Understanding of Engineering Messages, 2008). This report aimed to investigate the American public's understanding of what engineering is and what engineers do, and to provide a set of tested messages that might improve that understanding. The report noted that "[c]urrent and past engineering outreach to the public and message development have been ad hoc efforts…[and] although a variety of useful tactics have been tried, no consistent message has been communicated, even among projects by the same organization" (p. 4). The report also remarked that "[m]ost current messages are framed to emphasize the strong links between engineering and just one of its attributes—the need for mathematics and science skills. In other words, current messages often ignore other vital characteristics of engineering, such as creativity, teamwork, and communication" (p. 10).

This report comes at a time of significant professional reflection in the engineering education research community on the nature of engineering and engineering beliefs, values, and knowledge (see, for example, Grimson, 2007; Heywood, 2008a, 2008b; Heywood, Smith, and McGrann, 2007; Heywood, McGrann, and Smith, 2008; Royal Academy of Engineering, 2008; Smith and Korte, 2008), which has been made particularly visible by the inclusion of an "engineering epistemology" category within the engineering education research framework laid out by the Engineering Education Research Colloquies (2006). In addition, the NAE report was published shortly after the Year of Dialogue by the American Society for Engineering Education (ASEE), which has spurred leading engineering education researchers to articulate their manifestos on the future of engineering education (see, for example, Fortenberry, 2006; Gabriele, 2005; Haghighi, 2005; Shulman, 2005; Streveler and Smith, 2006; Wormley, 2006). Together, these two discussions, one of the public images of engineering and the other of the future directions of engineering education, intend to influence not only engineering outreach activities, but also the practice of engineering faculty in how and *what* they teach as engineering.

However, it is unclear that mainstream engineering faculty members value these same conclusions, let alone make decisions about what to teach or research based on these public treatises. How do engineering faculty in the U.S. view their work of educating engineers? This paper works to uncover the daily "disciplining" work of constructing and reconstructing a discipline,work that results in defining engineering alongside any public outreach campaign,that engineering educators do in their teaching, research, and service within schools of engineering. This paper documents three narratives that research participants used to explain their work to others as well to themselves: namely, that engineering is about *applied science and math, solving problems,* and *making things*.

In this context, narratives are familiar, even normative, ideas and explanations that follow a familiar discursive or ideological route, that are strongly situated in time and space. They are rhetorical tools that groups of people (here, engineers) use to accomplish certain discursive tasks (not to be conflated with simple stereotypes or generalizations) that have real-world consequences in how people behave. Investigation of engineers' narratives has tended to happen outside of engineering research (exceptions include Adam, 2001; Broome and Peirce, 1997); however, engineer and educator Bucciarelli (2003) has argued for the discursive analysis of engineers' stories about themselves and their profession:

> Engineers do construct narratives, not very fancy ones perhaps, but subtle in ways […] It is quite common to think that the explanations of engineers are objective, scientific, one-dimensional, lacking in ambiguity, trope, or metaphor. To see that it is otherwise requires we pay full attention to the way instrumental reasoning is embedded in text and to allow that the form of argument and the language used, in short, the rhetoric of engineering is part and parcel of instrumental explanation (p. 6).

The particular narratives described in this paper are called "universalized" not to imply these stories are enduring over all of history or across the globe, but because of how they *currently* portray a specific engineering context—engineering within an American engineering education system—as broad and undifferentiated, with little localized variability or heterogeneity of practice. At the same time, the regular ways that study participants themselves defined engineering did not accurately describe engineering as embodied in either their own practice of engineering in academic contexts, as they themselves recognized, nor in a mythologized "real world," even within the American engineering context.

The naming and exploration of these narratives, directly grounded in the data of participants' interview responses, allows engineering educators to start "seeing" (Bowker and Star, 1999) the disciplining work that they regularly do that constructs the practice of academic engineering. This research therefore provides engineering educators with an initial platform to start to interrogate whether these are the narratives *we want* to use to bound the edges of our profession, as these narratives may have significant consequences (as indicated by the NAE *Changing the Conversation* report) in terms of who decides to become an engineer in the future. In this way, this work contributes to the developing research area of engineering epistemologies (Engineering Education Research Colloquies, 2006).

II. Background: Defining "Engineering"

On its Web site, the NAE has provided the following response to the question, "What is engineering and what do engineers do?"

> Engineering has been defined in many ways. It is often referred to as the 'application of science' because engineers take abstract ideas and build tangible products from them. Another definition is 'design under constraint,' because to 'engineer' a product means to construct it in such a way that it will do exactly what you want it to, without any unexpected consequences.
>
> Engineers are men and women who create new products. It is estimated that there are over 2 million practicing engineers in the United States. They work in fields such as biomedicine, energy, automotive, aerospace, computers, and many others that require people to create products that didn't exist before (National Academy of Engineering, 2009).

In this statement, the NAE defines engineering *as* something that engineers do, and defines it through its relationship with other disciplines or through the production of various products. This response provides a paradoxically hazy definition about professionals who, in their work, often require a great deal of precision. Without knowing how the NAE defines "product," one could argue that an academic who writes a book on how food is portrayed in Victorian novels has created a product (the book) based on abstract ideas (theories about the historical display of food). Or, perhaps closer to home, a medical researcher who develops a new and cheaper treatment for AIDS could be considered an engineer by others although she considers herself a "scientist." With this broad definition, almost anyone could be described as an engineer. The next question might be, so what? Is it a problem for the category of "engineer" to be broad enough to apply to anyone who chooses it as part of their identity?

The history of the engineering profession might suggest that it is indeed a problem, arguing that engineers have strived to professionalize themselves ever since the mid-1800s (Layton, 1971; Noble, 1979). The very act of professionalization is one of boundary-drawing (Gieryn, 1999). Certain qualifications admit individuals into certain groups with particular status, and other qualities may restrict membership (Abbott, 1988). Layton (1971) describes the historical co-development of several American engineering professional societies, finding ample documentation in the historical record of the boundary differentiation and disputes engineers engaged in amongst themselves in order to carve out disciplinary territory from each other and from other professions in order to preserve autonomy, status, access to resources and so on. The development of licensing codes followed a similar pattern: Pfatteicher (1996) has described how, in the early 1900s, civil engineering and architecture overlapped to such an extent that the architects were claiming tasks as "architecture" that civil engineers thought were "theirs" within their ontological jurisdiction, causing civil engineers, motivated by the drive for self-preservation, to enact licensing codes.

These boundary-defining activities made use of sets of existing social institutions to simultaneously define what engineering was: educational, organizational, legal, or employment-based characteristics, rather than a set of skills, knowledge, or philosophical beliefs. These definitions used a constellation of social markers, a college degree, membership in a professional organization, to lean heavily on engineers' constructions of their identities, rather than on a description of engineering activity (Pawley, 2007, 2008).

Some have argued it is not much of a problem to have broad definitions. In fact, Koen (2003) uses the expansiveness of his definition of engineering (via the engineering method, which is "the strategy for causing the best change in a poorly understood situation within the available resources," p. 7) to argue that the engineering method is in fact a universal method, "a method that subsumes all methods" (p. 3). In contrast, Davis (1996) has argued that it is indeed important to have a widely-accepted definition of engineering, because definitions "determine who is eligible for admission to engineering's professional societies, who may be licensed to practice engineering, and who may hold certain jobs" (p. 97), a clear case of boundary-drawing and differentiation. From one perspective, the production of identity stories helps group members track "their" progress; however, another perspective is that this differentiation matters in order to set the "true" engineers from those of lower professional, intellectual, or simply verifiable quality. This latter setting of exclusive definitions undermines the rhetoric of inclusiveness prevalent in the discourse of diversity in engineering.

What is missing from most of these articulations of engineering is a direct connection with current engineers' actual language used to define engineering. In an academic context, exploring engineering faculty members' definitions of engineering as they articulate them helps us understand how their definitions govern their practice as academic engineers. Making this grounded and tightly-bound connection between the data of engineering faculty members' language and the broader narratives that construct and (re)define engineering is the focus of the research in this paper. Although it is beyond the scope of this paper, future research must explore how faculty members' narratives and definitions might influence the next generation of engineers.

III. Methods

This research is qualitative and has as its main purpose the development of a theory that allows the critical investigation of engineering's disciplinary boundaries. The research is based on data gathered from ten individuals selected from a school of engineering at one university. A small sample was chosen in order to develop rich descriptions that would help us understand the depth of experience involved in participants doing their daily work. Participants included people from most departments within the engineering school, both men and women, at the assistant, associate, and full professor level, including some with administrative appointments in addition to their faculty appointments. Because the main part of the study focused on understanding how faculty negotiated different disciplinary boundaries, study participants were invited to participate because of their service on engineering school standing committees, or because they listed multiple departmental affiliations on their school Web site.

Interviews are commonly employed to collect qualitative data in science and technology studies, engineering studies, and women's studies, and have been used to understand university interdisciplinary research and teaching (Lattuca, 2001). This study employed semi-structured interviews: the majority of questions were determined ahead of time, but the order or wording was modified on site, and additional relevant questions were posed, depending on the interviewer's perception of the flow of the interview (Robson, 2002). For example, some of the data reported in this paper came from responses to interview prompts such as "How would you define what engineering is?" or "Do you consider yourself an engineer?" However, some of it also came from participants' responses to other, more conceptually "distant" questions such as "How do you train graduate students to be good engineers?"

Sequential pairs of interviews lasted for a total time of 2.5 to 4.5 hours. The first interview focused on participants' definitions of engineering, their identity as engineers, and their research; the second interview focused on their teaching, service, and two specific questions on gender conducted at the very end in order to not confound the rest of the interview.

Upon the completion of each interview, an interview summary form (Miles and Huberman, 1994) was completed to aid in the systematic distillation of raw interview responses. Questions on the interview summary form were:

1. What were the main issues in the interview?
2. Summarize the information you got, or failed to get on each target question.
3. Anything else interesting, salient, illuminating, or important in this interview?
4. What new (or remaining) target questions do you have in considering the next interview?

Information recorded after a first interview was used to prepare for the second interview; the first part of the second interview was used to clarify issues from the first, and to ask any questions from the protocol that had been skipped.

The interviews were transcribed almost verbatim (excluding crutches of speech) following a transcription style sheet to maintain the same conventions for conversation objects like pauses and interruptions, and to preserve consistency of punctuation.

The transcripts were then thematically analyzed in two waves: first to identify text that used explicit metaphorical concepts associated with boundaries (such as edges, margins, borders, or using the word "boundary" itself; for more examples, see Lakoff and Johnson, 1980), or more implicitly differentiated one idea, process, concept, discipline from another. Next, the identified text was coded again more finely to classify and organize the boundary ideas into a framework that helped describe how participants interacted with this metaphor. The framework of narratives described here emerged through participants' differentiation of "engineering" or "engineering work" from other ideas (including through relationships with other disciplines like science, math, and technology, or in the context of engineering undergraduate degrees compared to other types of degrees, or in contrast to the kinds of industrial-situated work done by people with different job titles than "engineer"). This coding structure allowed for the characterization of the qualities of metaphorical boundaries experienced by participants in the context of their work, as well as highlighting the kinds of ideas/things they needed to recognize the differences *between:* the conceptual regions that the metaphorical boundary differentiated.

Throughout both the broad and fine coding periods, I wrote research memos (Miles and Huberman, 1994) as a record of my thinking at the time of coding, and to serve as a form of triangulation in addition to the interview summary forms and the interview transcripts themselves. The use of these multiple data collection sources improved the study's validity, as well as allowed me to measure what I was interested in more consistently and reliably.

Most of the interpretation of the results occurred during the process of writing this research, again following Miles and Huberman (1994) and Denzin and Lincoln (2000). The articulation of ideas into a narrative structure allowed for the space to organize and develop the themes that emerged through the broad and fine coding periods. Ideas that did not stand up to this writing were cut, while ideas that held together both across analytic themes and participant interviews were expanded upon and remained in the document. The results are presented in the form of text representing participants' speech in interviews, with additional analysis informed by the history of the profession or theoretical frameworks proposed within science and technology studies to put the text in a broader theorized context.

This discursive approach to qualitatively analyzing data (Gee, 2005; Miles and Huberman, 1994; Robson, 2002) helps build a theory about faculty members' definitions of engineering based on the strength of ideas rather than based on, say, the frequency of the articulation of a concept or comparison group. In addition, this method applied to a small number of participants does not permit the generation of one single consensus-based definition of engineering, nor does it try to test participants' definitions against each other. Instead, the small number of participant interviews allows deep and descriptive analysis that can form a grounded initial theory for further exploration in subsequent research.

Participants were not asked to verify whether the analysis and conclusions of this work accurately represented their thoughts (the process of "member checking" (Robson, 2002)). In part, this is because the research is about applying a certain analytical framework to analyze participants' discourse, irrespective of their intent. However, before analysis began, participants were given the chance to verify the transcripts themselves for accuracy, and were invited to clarify or elaborate on any aspects of the transcript.

In many cases, this paper is based on long participant quotations rather than paraphrased statements or summary quotations. These long quotes are a form of data display, and because of the nature of the data, extensive reduction can lead to loss of relevant information. The way each quote hangs together—through the actual language used, through its context, and often messily intertwined with all sorts of other ideas—seems crucial for understanding what each person was trying to say. In addition, just as definitions are social, Gee (2005) argues that "validity is social" (p. 154), by which he means that validity is socially constructed by the readers and interpreters of the research. To help make a convincing case to readers that the analysis and conclusions present in this study are valid, as much interview data has been included as relevant without being unwieldy. The presence of the data themselves allows readers to decide whether the analysis is believable or not.

To preserve participants' anonymity while providing enough detail to keep quotations in context, several different writing conventions were employed (similar to Foor, Walden, and Trytten, 2007). Questions asked by the interviewer are included where needed to help with comprehension, and are prefixed by "Interviewer:." Where a participant's or interviewer's words have been excerpted, the cut is marked by "[…]." Where participants used language that could potentially identify themselves, their department or the university, those words have been deleted, and if needed, replaced with generic versions (such as "[an engineering department]" or "[the university]"). Words added to help clarify quotations (such as when referents are not included in the quote) are also marked by square brackets. When the recording quality made the participant's speech unclear, the text in doubt is marked by square brackets with a question mark at the end (such as, "[climbing the ladder?]").

In reporting this research, I have wrestled with the decision of how to refer to each study participant's gender. My initial decision was to avoid referring to participants' gender wherever possible, as I did not want participants' thoughts to be interpreted as "just like a woman to say that" or "only a man would think that." This research is not about whether an individual participant describing a particular idea was male or female; instead, it is about the idea the participant was describing. In addition, writing about the study participants' speech without referring to their gender wherever possible could prove an interesting ethnomethodological disruption of normal American prose, which is often structured around gendered pronouns as though it is always important to know the gender of a person speaking or acting.

At the same time, I was concerned about how I represented my participants. While they had been assured in the study's consent letter that key details of their interviews, including department or discipline, might be omitted to preserve their anonymity, I did not consider asking them how they might feel if their comments were repeated *without* those same key details. Kolko (2000) has written about the beginning of online role-playing games and the decision of early (white, male) gamers to exclude race as a public player characteristic because of their assumption that participants would want to, as it were, leave their race in the "real world." Kolko has argued that this decision functioned to "whiten" cyberspace until other gamers, those who wanted race to remain a recognized aspect of their identity, argued for the reinsertion of a "race" category in social online forums. Would my decision to exclude gendered pronouns function to gender text unintentionally, while simultaneously removing from participants the right to be identified as women or men?

Because I could not be sure what my participants' preference would have been, I have written this document using as few gendered pronouns as I could to preserve anonymity. I structured the narrative without gendered pronouns except in direct quotes.

IV. Analysis

Participants' definitions of engineering tended to fall within three narratives: engineering as applied science and mathematics; engineering as solving problems (in their words, particularly "more real" problems or problems "that mattered," in contrast to scientists); and engineering as making things (although varying in how engineers actually interacted with construction of "things" and what the "things" turned out to be). These definitions are called "narratives" because of the sense that their definitions were familiar stories that they had repeated many times before to define engineering. While the narratives did not quite have a formal beginning, middle, and end, they seemed as well-worn as paths, or as well-rehearsed as scripts, metaphors which could also serve as description of these definitions. They are called "universalized" because they were portrayed as applying globally, although they tended to become less so when specific questions were asked about them. Indeed, the narratives themselves may seem quite ordinary and unremarkable, until one starts probing the specifics and finding the contrasts between engineers and technicians or scientists, or where women and women's work could have been but were not a part of engineering (Pawley, 2007).

A. Engineering as Applied Science and Math

The domain of knowledge that participants most often linked to engineering was science. Participants often highlighted engineering's similarities to and differences from science, but at the root was a basing of engineering on a foundation of science, as demonstrated by this quote from a full professor: "I think it's the application of science and models, mostly science, to problem solving."

An administrator felt similarly, and described at length how science was the "bedrock" of engineering, and how differences and disciplinary boundaries have disappeared (or will disappear) as all subjects reach the same science bedrock:

> If you go back a hundred and fifty years, you have sort of philosophy which was physics, primarily. But that was too tough to handle as a field, so we broke physics apart and we broke engineering out of physics, we broke chemistry out of physics, we broke biology out of physics. We even broke physics apart, into high-energy physics, low-energy physics, nuclear physics, solid-state physics. […] We drilled down to the scientific bedrock of understanding, and each of these engineering disciplines and each of these science disciplines, we came to the same common bedrock.

In contrast, some participants explicitly differentiated engineering from science by pointing out engineering's applied character in contrast to science, and suggesting that engineering's work somehow mattered more than science's because of how it solved "real" problems.

One of the ways that participants linked engineering to science was using mathematics as foundation to the science and engineering curricula. An administrator used mathematics as a precursor for understanding science, itself a basis of engineering, saying:

> But before you teach them science, you have to teach them the language of science—that's mathematics. So if you go back to the traditional engineering education, you would bring in the students their first year, you stick them in calculus, physics, chemistry. Give them mathematics, the language of science, and you give them science.

Here it is a connection with science classrooms that makes a curriculum "traditional engineering," therefore the language of math becomes important for both. An assistant professor also used the metaphor of language to describe the import of mathematics to understanding science and engineering:

> And then fluids is really, the purpose is quite different. This is the first class in which you have to interpret equations, and differentials have meaning, physical meaning. And so I look at this class as teaching students to read math. Teaching students the language of engineering.

Math is more than a foundation or a language for some participants, it also is a defining marker, important in the drawing of boundaries around the engineering curriculum. A full professor said:

> Engineers generally do a lot more mathematical kinds of things, at least the curriculum requires a lot more mathematics than does most any other major on campus-with the exception of physics or math.

An assistant professor, trying to differentiate engineering undergraduates from science undergraduates, said:

> Maybe it is that engineers take more math and physics, and the biologists maybe are doing more chemistry and biology.

So for these participants, engineering is a connection to certain sciences more than others.

According to other participants, however, these relationships were changing because of engineering's developing relationship with biotechnology. One administrator said:

> But I think when you think about what engineers do, I have a saying: 'Look around you and look at all the human-made structures you see. All of those have been engineered.' That's what I used to say. Now what I say is: 'Look around you. Look at all those human-made structures you see. They have all been engineered and some of the plants have been, too.'

This quote simultaneously emphasizes the applied nature of engineering, the design and production of all the "human-made structures you see."

One full professor stressed the importance of math specifically to the point of declaring math responsible for one of the major "crises" facing engineering: the shortage of engineers in the U.S. labor market. This participant started by professing a personal preference for mathematics:

> I like math. I'm not a mathematician, but I like math. And so, and engineering has a lot of math in it. I was surprised how little math there was in most other disciplines, compared to engineering. […] I mean, you were asking about why there are so few people in engineering, it's because nobody wants to do any math.

So while mathematics served for some as the "language" of science or engineering, its presence explained differences between engineering and science for others.

The quotes in this subsection demonstrate how the relationship between science, mathematics, and engineering was used to define engineering by many participants in a sort of relational ontology (Breslau, 2002) where engineering applied science using a mathematical language, and how participants allowed this relationship to interact with the other universalized disciplinary narratives.

B. Engineering as Problem-Solving

Across almost all the interviews, in combination with the other narratives or alone, participants described engineering as some form of problem-solving. A typical example can be seen in this assistant professor's description:

> So an engineer takes a problem, takes a need, a human need, applies physical laws, physical behaviors and tries to derive from that, or [design?] from that a solution to that problem that meets that need.

Frequently, part of the definition involves specifying a connection to the human aspect of these problems—engineers solve societal problems, or problems as defined by society. There is also sometimes a connection to the definition of applying science in some way. However, few participants articulated who they were talking about or what they meant in terms of "society." When asked where the problems came from, an assistant professor said:

> I like solving problems, so to me it's just like they're there, and I see them and I find them, I just… I think it's interesting, so maybe I make up problems because I like the solving part of them.

This participant talks both about "finding" problems as if they were already constructed, like boxes to pick up, as well as about fabricating them in order to solve them. Both modes seem to be in contrast to the idea that "society" makes the problems, but are similarly underexplored by participants. One might consider why it is rhetorically valuable for academic engineers to discursively separate themselves from society in discussing their work.

Participants' descriptions of engineering and engineering's connection to problem-solving left space for some flexibility. An associate professor started off describing engineering, and provided additional limits to differentiate engineering sub-disciplines from each other:

> Engineering is problem solving, and chemical engineering is problem solving using chemistry as well as math and physics. […] That's general enough, it's hard to argue against. People would fill in how much biology you need, and what type of problems, and some people would want to specify who our customers are, and other people would want to talk about old industries and new industries, but I think talking about engineering as problem solving, it's specific enough to be a useful focus, but it's general enough to include almost everything our students end up doing.

In this definition, the participant situates chemical engineering in relation to a more general engineering, and in the context of different customers or industries. The participant indicates some aspects that vary between practitioners ("people would fill in…"), as well as some considerations for how generic to make the definition. For this participant, making sure the definition encompassed the careers of department graduates was a litmus test, additionally noting that people perhaps might categorize problems differently.

Some participants included in their definitions a hint at how they had learned this narrative of engineering as problem-solving. An assistant professor credited a mentoring committee member:

> One of my mentors actually told me that the way that he did things just between the scientists and the engineers, the engineer is someone who takes the skill set and applies it to solving problems, and it can be lots of different types of problems, so the research portfolio can look a little bit schizophrenic because you're sort of doing all these different things. But you're taking similar approaches in each of them. Whereas scientists will focus on one particular system or one thing and study it in really great detail and use lots of different tools to study it.

Here again engineering is contrasted with science through the "solving problems" paradigm, although the connection is complicated a bit by notions of depth and breadth ("it can be lots of different types of problems, so the research portfolio can look a little schizophrenic" compared to "study it in really great detaill"), and the interaction with "tools," (one skill set applied to "lots of different types of problems" compared to "lots of different tools" to study one thing). Other sources of definitions included participants' undergraduate experiences (one assistant professor called it "brainwash[ing] into thinking engineering's something special" from science or math), their tenure experiences or those of colleagues, and their Ph.D. experiences or those of colleagues.

The narrative of engineering as problem-solving brought with it several sub-forms, which both served to differentiate engineering from science while simultaneously placing engineering as an obligatory passage point (Callon, 1986; Roth and McGinn, 1998) between a conception of scientific research and societal applications. Each sub-form is related to a concept of utility to society, where the consequences of "engineering solving problems" have an almost heroic flavor (Adam, 2001; Broome and Peirce, 1997):

1) Engineers solve problems that matter: This connection of engineering to problem-solving connects to the strategy of arguing that engineering outcomes matter more and act more directly than those of science, as mentioned in the previous section. An associate professor used the idea of problem-solving to distinguish the work of engineers from the work of scientists (in this case, chemists), saying:

> Particularly, for experimentalists, having a physical product that has a particular purpose and application. For the chemists, it might be good enough to have a reaction, and say, 'Oh, this reaction creates that. Boy, isn't that interesting.' Whereas for the engineers, that reaction has to do something useful and have an application, and then be applied there and shown that it's actually solvent. I think the engineering distinction probably has most, in my mind, to do with the application to a particular problem.

While this argument was popular amongst participants, less common was a discussion of who defines utility, and how different things are understood as useful or not. As another example, a different associate professor had similar thoughts:

> Yeah, the motivation is that you can see an application, you know, and at some [name of discipline] departments they may actually be doing the applications themselves; around here, we're trying to sort of come up with the enabling technology for other people to spin it off and take the applications so there's a little bit more of an ivory tower flavor to it. But yeah, the idea that you do have an end use in mind, that you can see how it's going to be applied... one of my friends […] has a statement she uses in our intro course that [an…] engineer is somebody who can do for one dollar what a […] scientist can do for two dollars. […] So it's a matter of being more realistic and being more practical, and doing things that can actually be done economically. There's sort of that undertone of it, you know, first you have to show you can do something, then you have to make it effective compared to some yardstick.

Through this text, this faculty member articulates some of the values of engineering: valuing more "practical" applications, with less of an "ivory tower flavor," as well as integrating economic efficiency into the practice of engineering research. Perhaps economics, then, impacts utility; although, again, we do not know who proposes the "yardstick."

In a different example of engineers solving problems that matter, a full professor trivialized the work of scientists as simply "fun" compared to the work of engineers:

> Well, engineers have a purpose. You're always answering the 'so what' question. You don't do engineering research just because it's fun, you do it because it matters in some practical application. [...] All sorts of really interesting stuff that's very scientific, but it all has the eventual 'so what?' question attached to it. If you have no 'so what?' question, if you're just doing it because it's fun, that's science.

Through these series of quotes, the implication is that serious engineers solve certain kinds of problems in economic ways. What is important to recognize in all of these examples is how science is constructed simultaneously to engineering (Layton, 1971): engineering is "useful" and "practical" as compared to science being "fun" or simply "interesting," sounding detached and abstract, perhaps even frivolous. While science provided the most frequent comparison for engineering, it was often in the sense of a foil, where science's presumed disconnect from already-existing problems was a deficiency in the eyes of the engineering participants. Of course, were scientists asked about the application of their research, they also would likely highlight their work's contribution to solving society's problems. The arguments for developing a scientifically literate American public are based on this connection of scientific understanding to solving critical and global problems (see, for example, American Association for the Advancement of Science Project 2061, 1989). The disconnect between the rhetoric of engineers about science and scientists' perception of their work provides a question to explore in future work: How is engineering perceived by people from "outside;" people who identify as something other than an engineer, and where are the overlaps and disconnects?

2) Engineers "help society:" Another version that often hybridized the narratives of engineering as applied science and math and engineering as solving problems was the argument that the results of engineering "helped society" more than those of science. An administrator argued that engineering exists at a benevolent interface between science and society:

> Engineering is applying advances in science to meet the needs of society. Engineering is really where science meets society. That may have to do with building a bridge, building a building, building a car, building an iPod, building consumer electronics, fixing my computer. Or it can have to do with dealing with social interactions—how you engineer environments so that people interact in a much more supportive and friendly way. It has to do with all areas in which advances in science can be brought to bear to improve the quality of life of people to benefit society.

In this quote, the participant connected the products of engineering to everyday benign objects (iPods, computers, cars, buildings) and environments (to make them "more supportive and friendly"), in order to "benefit society." The participant did not include other, arguably more troublesome ways that engineering interacts with society, such as through its historical (Bix, 2005; Hacker, 1993) and persisting relationship (Riley, 2008) with the military, nor did they unpack the concept of "society" to explore who is actually meant by this term.

3) Engineering is "useful:" Some descriptions were connected less to the inherently beneficent nature of engineering benefiting society, and more to a generic "so what" and a conception of usefulness; this assistant professor described some research in contrast to physics:

> Yeah, I don't think a lot of our stuff is engineering. I think it's more science. But the problem is that the scientists are not really doing, they're, I'll—I shouldn't say that. A lot of the scientists are not doing useful research. So that's my applied side, right. They're just—you can publish—it's funny—you can publish in Physics of Fluids with a pretty picture and not have any use whatsoever. Nice pictures of drops and be able to say, we can correlate the size of these drops 9 times out of 10 by this equation which uses this... I'm sort of like, who cares? And it's not stuff that when I'm looking for useful stuff or looking to correlate our data I've—I mean I'm searching the whole database, that just doesn't come up on our radar screen that much. We're not doing particle physics or anything like that. Which, 30 years from now may be engineering, may be very applied. The stuff I'm doing now at one point was pure turbulence theory and was not very applied. But now it's applied as something—the tools are there, the understanding is there to design that information. So I consider myself to be, I guess, doing engineering, but some of it is not near-term applicable. Some of it is just trying to get the physics of the behaviors that are going on.

In this quote, we see the idea of a "distance" to application (as well as journal publications as the markers of a field). We also see one participant's conception of how a discipline changes over time. Also clear is the dismissiveness associated with "pretty pictures" that have "no use whatsoever," suggesting that engineers, in contrast, do things that matter, or are useful. We also see a tension here in how what was once "pure" research eventually becomes "applied" (Jesiek, personal communication, 2008).

While many participants argued that engineers' work had practical or important utility in the "real world," particularly in contrast to other kinds of work, when pressed for examples in their own work, they made use of spatial metaphors of distance to explain how their research wasn't really all that "useful." An associate professor said:

> It has to be plausible. You know, a lot of the stuff about renewable energy, a lot of the stuff about biotechnology, it's a long way away from being practical, but you can sort of imagine that it could be used... it's sort of like science fiction, you know, if a couple things change, then we'll need this stuff.

An assistant professor brought up the idea of closeness when describing the difference between certain forms of "fundamental" research, and linking engineering research with the idea of application:

> Participant: So if the funding agency is more fundamental, that's actually great for me, because I can write, I like the fundamental type work. Although I'm always focused on

application, that's what's different about what I'm doing. I'm not a—a physics proposal also has to have an application, but it can be, they're just better at stating, making up applications for their weird research. I just can't do that. They do; I've read some of the proposals, and they talk about how studying muons will help us understand the cosmology of the universe, which will eventually solve cancer someday. So, and it's great. I just can't do it when it's that far out.

> Interviewer: —So you mean that, do you mean far out in the sense that it's multiple steps to that—?

> Participant: —Abstract. Yeah. I've got to be pretty close.

Here we see engineering as an obligatory passage point (Callon, 1986) between "science" or "research" and societal application, and that there is "distance" between research and application. However, while the narrative of engineering as solving problems was exceptionally strong in that it flavored much of how many participants defined engineering, it also was rather weak in terms of explaining how engineering faculty members' own research might be considered engineering.

C. Engineering as Making Things

For some participants, what was critical about defining engineers, and what sometimes separated engineering from other disciplines (including science) was that people doing engineering "made things." Between participants, the type, character, and materiality of the "things" differed, as did whether such people should be called engineers or could have other identities and job titles. But the creation and production of a "thing" seemed important. A full professor explicitly defined engineering thusly:

> Well, engineering to me is building things or processes and such. Engineers are creating things, so if you want to know what it's all about, I usually say that there's the science part, there's the business part, and then there's the design part. Those are sort of the three things that define someone as an engineer, maybe.

This same participant went on to specify that "engineers" were not the only people to "do engineering:"

> Most everything you see around you that's been constructed in some fashion is the product of some form of engineering. Even if it wasn't done by engineers—if the people who actually created something weren't actually professional engineers, they might be said to have done engineering, even if they weren't doing that. I expect a lot of farmers do a lot of engineering when they're just having to build something—do something that way.

This theme of referring to the material objects that surround people as the product of engineering was quite popular amongst participants, including by an administrator (whose definition we have already seen in this paper) and an assistant professor (who also integrated a consideration of solving problems into the definition):

> But I think when you think about what engineers do, I have a saying: 'Look around you and look at all the human-made structures you see. All of those have been engineered.' That's what I used to say. Now what I say is: 'Look around you. Look at all those human-made structures you see. They have all been engineered and some of the plants have been, too.' (Administrator)

> So there's an engineer involved in everything that you will come into contact with. So everything from—everything. The air we're breathing is produced by HVAC engineers, the chair you're sitting on is, had to be approved by some engineer. So every product or process, there's an engineer involved. Or engineering was involved, I should say, whether or not it was an actual type of engineer [who] was involved. So an engineer takes a problem, takes a need, a human need, applies physical laws, physical behaviors and tries to derive from that, or [design?] from that a solution to that problem that meets that need. (Assistant professor)

Both these participants use engineering to describe a highly mechanized and technology-infused world, where everything one may come into contact with had been processed or created by some product of engineering. An advantage of this inclusive rhetoric is that engineering becomes everywhere; however, participants also risk diluting the definitions of engineering to the point of non-recognition (Jesiek, personal communication, 2008).

There seemed to be some attraction amongst participants to training engineering students to make "things" themselves; a participant described a classroom project, where "making a device" was used as a specific motivator for engineering students:

> What I ended up doing was making this mega-super lab which was like six different modules that incorporated not just this lab, but a bunch of other labs and managed to pull them all together into this thing that ultimately made a device. It was really cool. […] I think I threw mine out because it sort of disintegrated in the last couple years. I had one sitting on the shelf over here. It was something that the engineers could make. The engineers in the class—they've done this for three different classes now—they were like, 'Oh, yeah, this chemistry stuff's really useful!' For the first time in their lives, thinking, 'This is actually a useful lab!' […] And comments like, 'I learn by doing and for me to actually be able to make the device was so important. It was hard and it was a painful process and it took us all semester but at the end, we actually got something out of it.' There was a lot of excitement and interest. Even if they didn't have a functioning device, they had a device!

However, this same participant also recognized that the characterization of "making things" as defining engineering had problems, and, used boundary language ("a clean boundary"—language that differentiates two conceptual areas or in this case, disciplines) to describe the difficulty in the context of differentiating an engineering graduate student from a chemistry graduate student:

> Certainly … a physicist would argue that if you had a physics graduate student, they would be able to make

> something, too. And you can't delineate between an engineer and a scientist because of this difference between an engineer and a chemist. I'm not sure it's a very clean boundary. I also think a lot of it is what they had prior experience with. Because, in one case, after a couple years the student was making all kinds of stuff. And so having these three chemists was an interesting thing, too, because now I know all chemists are not equal. They're not all the same; they don't have the same personality, they don't have the same abilities. One of them kind of took to this stuff. 'Yeah, yeah, I get it.' After spending some time working with the engineers and seeing how it's done. Pretty soon, a couple years later, he's making his own stuff.

The theme of making things moved throughout participants' disciplinary narratives, in connection with the other ideas of engineering as applied science and math, and engineering as solving problems, although it was complicated by both what the "thing" was and who actually made it.

V. Conclusion

Three explicit disciplinary narratives were evident throughout participants' descriptions of engineering, situated within an American educational context. These narratives are "universalized" because of how participants used them to characterize engineering as homogeneous. These universalized narratives were around the ideas of engineering as applied science and math, engineering as problem-solving, and engineering as making things.

The first, *engineering as applied science and math*, described mathematics as the root of both engineering and science, but participants differed in terms of whether they thought engineering was more similar or more different from science. When participants described engineering as different than science, they described engineering as an obligatory passage point between science and society, but where engineering had more utility, or helped society more than science. The second narrative, *engineering as solving problems*, extended the connection of engineering to utility, to the notion of "real problems," and to solving problems that "mattered." However, participants also talked about the problems as being already formed, as something simply to pick up and solve, or as constructed by an amorphous and disembodied "society," not by engineers themselves; they also admitted that there was often some "distance" between their work as academic engineers and an actual application or solution. The third narrative, *engineering as making things*, connected engineering to the physical construction of highly technical and mechanized products, both as a motivator for engineering undergraduates and as a way to differentiate science graduate students from engineering graduate students. Each of these narratives is conceptually distinct, but almost always appeared in the company of other narratives, suggesting the narratives are used in hybrid ways.

It is not anticipated that these narratives on their own are surprising to readers. In fact, they have been articulated in various ways—by scholars working in the area of the philosophy of engineering, including Bucciarelli (1994, 2003), Vincenti (1993), and Koen (2003). The contribution of this paper, then, is its tight connection with the language of practicing academic engineers in the US. These narratives are literally the stories engineering educators tell, and we tell them to ourselves as much as others to make sense of our own experiences of the broader profession of engineering.

The narratives outlined in this paper organize the definition of "engineering" in the minds of faculty participants who form the initial contact interface between undergraduate students and the profession of engineering. These data themes are not intended to argue that the narratives, in fact, constitute how engineering *should* be defined. Instead, these data are examples of how faculty use these narratives to explain their discipline, irrespective of whether or not the examples reflect some broader truth. The explanations themselves are important because they, through the repetition and articulation of the narratives to other people (in particular to undergraduate students), *continuously construct, reproduce, or resist* the disciplinary boundaries of engineering themselves (Pawley, n.d.). Participants both directly and indirectly construct the engineering discipline through these narratives: the former, through their actual academic engineering practice, such as in mentoring relationships, guiding research programs, and determining course content (as has been seen in this research), and the latter, as others may use them as guidelines for deciding whether or not they want to participate in such disciplinary space. The narratives simultaneously model and construct "engineering" for the faculty members themselves and for others within the disciplinary space of academia.

This epistemologically fundamental research makes visible multiple threads for future investigation. Most directly, researchers should look at how undergraduate students interpret, learn, or otherwise make use of these narratives in different ways (such as to help make course or major choices, or to justify their future career paths to family and friends or even to themselves). We should look to see how students reproduce, modify, subvert or otherwise resist such narratives, both privately and publicly, as they set out their future educational and career plans, and whether they generate and even embody new narratives about engineering. Researchers could use conclusions from this research in the context of the NAE *Changing the Conversation* report to investigate whether particular student populations respond more or less strongly to these narratives, and what evidence students need to see present in their classroom content and practice to believe alternative narratives about engineering's professional interest in and capacity towards, for example, solving the grand challenges of our planet (National Academy of Engineering, 2009).

However, naming the narratives also helps make them available for critical analysis. If we as engineering educators fail to name and unpack our own stories, we risk carrying on the way "it's always been done," maintaining the discipline upon its historical and arguably exclusive foundation. The NAE's call for "changing the conversation" is a valuable one in terms of the messages engineers use to describe the profession. The ideas they offer in replacement may form a compelling new vision of engineering in the minds of the public, including engineering as a creative, innovative, and inspirational field (Committee on Public Understanding of Engineering Messages, 2008). However, it is critical that engineering faculty not only share these new messages with students, *but also model them for students through the practice of their teaching, research, and service*; otherwise, the messages are simply sound and fury, signifying virtually nothing for the next generation of engineers, and making little difference to the discipline as a whole.

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