Gendered boundaries: using a “boundary” metaphor to understand faculty members’ descriptions of engineering

Alice L. Pawley
Department of Industrial and Systems Engineering, University of Wisconsin-Madison
Madison, WI 53706 pawley@cae.wisc.edu

Abstract - Programs and theories that form around women’s underrepresentation in engineering tend to use pipeline or chilly climate metaphors for their theoretical foundation. This paper investigates a metaphor new to engineers, that of “boundaries,” to help make visible the disciplinary work engineering faculty members regularly do that could construct academic engineering as a gendered field. Through quotations drawn from an interview-based study of 10 engineering faculty members, I explore ideas of boundary language and work, and suggest ways in which the conceptual boundary of engineering can be interpreted as gendered. This paper provides CSET audiences with a new “tool to think with” when considering gender in engineering.

Index Terms - disciplinary boundary, engineering faculty members, gender, defining engineering

INTRODUCTION

Much of the program-based and theory-based research on women’s continuing under-representation across CSET disciplines illuminates the individual and institutional barriers women face by focusing on their direct experiences ([1] e.g. [2], [3]). Theoretical models that emerge from these studies often invoke one of two conceptual metaphors [4] to help them make sense of women’s experiences. This paper proposes a third, the boundary, and provides examples of boundary language and boundary work from an interview-based study of engineering faculty members. Further, it suggests ways that the idea of boundaries can help analyze the content and ideas that define engineering, and investigate whether the conceptual borders of engineering itself could be considered as gendered.

This research provides CSET audiences with a new tool with which to think: understanding both how boundaries can be interpreted in engineering and how engineering faculty members engage in boundary work can help us understand the socially-influenced choices that determine who can be engineers and what engineering is. It is hoped that this conceptual tool proves useful in developing new theories about women’s persistent underrepresentation in CSET disciplines.

Metaphors to understand women’s low numbers in CSET

Frequently, programs designed to address women’s persistent underrepresentation in CSET disciplines employ “pipeline” metaphors or “chilly climate” metaphors, or a combination of the two (for example [5], [6]). Pipeline models [7] consider the scientific educational system a pipeline, where unformed scientists enter at the inlet, completed scientists exit at the outlet, and certain populations (namely women and people of color) leak out along the way. Programs that employ this model attempt to “increase the flow” of those underrepresented populations into the inlet by increasing access to scientific and technical programs, and plugging the aforementioned leaks. Chilly climate-based models [8] are a subset of the pipeline metaphor, and suggest that the leaks are caused by a “chilly environment” that discourages people already under environmental stress (again, women and people of color) from remaining. Programs that attempt to stem these leaks provide metaphorical “sweaters” - “survival tools” for underrepresented populations to better withstand the chilly environment - or train their white male peers on how to increase the “thermostat” by implementing, for example, parent-friendly tenure procedures, gender-neutral hiring protocols, or the much-maligned idea of “sensitivity training.”

While these metaphors have constructive conceptual components, they leave uninterrogated both how we define “engineering” and how we use “gender” as a category to understand women’s underrepresentation in engineering. I have argued [9] that women’s underrepresentation might also be investigated using a third, more indirect, research metaphor: that of a “boundary.” A boundary is not a physical thing in this context, but an idea that researchers can use as a tool to understand people’s experiences. It is not a defined “line” but, rather, is located along the margin of a clump of accepted practices; this edge may be determined differently by different people. For example, current engineering educators use language associated with boundaries to characterize content and identity characteristics as “engineering,” or “not engineering.” The language and ideas of boundaries, however, likely vary to some extent. The conceptualization of this metaphor is well established in science and technology studies [10]-[12], sociology, [13], and studies of disciplinarity in academia [14]-[16].

In fact, historians and sociologists of science have argued that the historical boundaries of engineering (and engineering
education) encompass a group of accepted practices structured by socially-influenced notions of “men’s work.” Similar practices, marked as “women’s work,” were the purview of home economics departments, [17], [18] despite overlapping conceptual characteristics (e.g., mathematics in textile production, [19], mechanics and electronics in household equipment [20]). Constrained by an educational system structured by such social norms, women became “home economists” more often than they became “engineers.”

To more fully understand contemporary women’s underrepresentation in engineering, we must consider where academic engineering’s boundaries are today. How do modern engineering faculty members understand, influence, reproduce, or resist engineering’s historically gendered boundaries? This paper describes results from an interview-based study of both men and women engineering faculty members at a research-oriented university, focusing on how faculty implicitly or explicitly describe the boundaries of engineering, and how their descriptions reproduce or resist historically-influenced ideas about women’s and men’s work.

**GENDER AS A CATEGORY OF ANALYSIS**

“Gender” in engineering education research has tended to signal that the work being reported studies some aspect of women’s experiences in engineering. It also has tended to presume that the correct scale to use to measure and record “gender” is one of the dichotomous categories “male” and “female.” (Notable exceptions to these two points include [21]-[23].) Scholars in women’s studies and gender studies have eschewed such under-theorized decisions [24], and argued that gender is a concept that is related to social characteristics that we define as “male” or “female.” At the historical heart of these characteristics may be a belief that they are related to certain biological differences between people defined or identifying as males or females. Key is the recognition that such characteristics are socially constructed, and are determined differently by different cultures, and at different times.

Using such a definition allows us to consider the idea that ideas and objects, as well as people, can be considered “gendered” in cases where the impact of such ideas, objects or processes are differentially experienced by people of different genders. For example, a hairbrush may be considered “gendered male” through its design, packaging, and marketing in order for it to be used disproportionately by men. A job may be “gendered female” through its design, resource allocation, and requirements for success in order for disproportionately more women to succeed in it than men. However, gendering need not be intentional to have an important impact.

The broader research project from which data for this paper is drawn uses gender as a category of analysis based on symbols that construct gender, social rules which make use of these symbols, and power relations that are constructed from such social rules [25]. In the third section of this paper, I look at some examples of how faculty members’ descriptions of engineering reflect beliefs about the gendered nature of engineering.

**STUDY METHODOLOGY**

Two research questions investigated in this qualitative study are:

1. Can a boundary metaphor aid in understanding engineering faculty members’ explicit or implicit descriptions of engineering or their sub-discipline within engineering?
2. How do faculty members’ descriptions interact with historically and socially influenced ideas about women’s and men’s work?

Ten faculty were interviewed from an engineering school situated in a large research-extensive university to help answer these questions. These faculty were selected from a pool of potential participants formed through the participation lists for standing school-wide committees. The selected group of participants were chosen to provide a balance of disciplines, faculty ranks, administrative roles, and men and women. Only one person from this selected group declined to participate.

The pilot-tested interviews were semi-structured and usually were conducted over two periods of 90 minutes each, although the total time varied from 149 minutes to 249 minutes. Questions having to do with defining engineering, identity, and research were included in the first interview, while questions having to do with teaching, service and gendered disciplines were in the second.

Interviews were transcribed and first coded with broad codes associated with the study’s research questions, namely “identity,” “defining engineering,” “pressure agents,” “boundaries,” and “gender.” For this paper, text that was coded as “boundaries” was reanalyzed with a set of finer-grained codes that emerged from the data. Examples from this subset of fine-grained codes were used to illustrate the argument of this paper.

**UNDERSTANDING “BOUNDARIES” IN ENGINEERING**

This section provides examples of faculty members’ interview responses that particularly demonstrate the idea of a boundary, and that suggest an answer to the first research question above.

**Boundary Language**

Feminist science scholars have observed the metaphorical nature of language used in scientific scholarship [26-28], noting that because metaphors have the power to illuminate and communicate ideas, they also structure how we think, theorize and solve problems. Analyzing faculty members’ interview responses for language associated with “boundary” metaphors yields a rich lexicon of terms related to the complicated characterization and categorization [13] of ideas and values associated with engineering.

Some of the faculty members’ language explicitly expresses the idea of boundaries, even making use of the word itself. A full professor described the impact of licensing on his idea of what an engineer was:

“And so when you use "professional engineer," that would indicate to me that I as an engineer have taken on yet another role, or I've assumed because of that licensure that my
engineering is not just to be done based on any whims that I have about it. That it has some constraints, some boundaries.”

Other responses were more interpretive, through faculty members’ use of adjectives, verbs, and additional metaphors. As an example, an associate professor describes some difficulties experienced in trying to find a location for a mechanics class that required a fume hood:

“[The building designers] weren’t thinking ahead of the interdisciplinary nature of the research that we’re doing is going to go into the teaching that we’re doing and pretty soon, the divisions between chemistry and physics and engineering are going to get less and less crisp.”

So while the quote includes an idea of a division, it is the adjective “crisp” which gives an indication about the character of the boundary between engineering and two physical sciences.

Another example is from a full professor describing how it feels to do interdisciplinary research. In this quote, the faculty member makes use of a metaphor of a street, where the “land” of disciplines are separated by the boundary of a street:

“But when you live at the intersection of two disciplines you -- and intersection is probably not fair. I would have thought that ten years ago, I don’t think that now. I think I live on a street where there’s two disciplines on either side and I live in the middle of the street.”

This faculty member continued by comparing interdisciplinary work across two schools within the same university to doing single-disciplinary work in engineering:

“[M]ost of the faculty in both schools are single-discipline based, so the students aren’t used to listening to a multidisciplinary framing of things. And they’re not used to thinking about the fuzziness of ideas. They’re used to thinking about the precision of the ideas. And so, to enter into a conversation where there could be multiple ways of characterizing a problem, and multiple ways of solving it is not something that happens in other classes.”

Here, “fuzziness” and “precision” are used to describe disciplinary ways of thinking, which implicitly indicates where the conceptual boundary resides between the two.

Faculty members also used language that can be understood through the boundary metaphor when describing relationships and distinctions between disciplinary areas. In this extensive quote, an administrator suggests how science and engineering are conceptually linked, and yet considered to be different, through a description of the history of engineering:

“We drilled down through the last hundred... fifty, seventy-five years, really. 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 [...] Basically, it all comes down to the atomic level. Understanding matter and matter interactions at the atomic and elemental particle level. What we did in the last century, I'm told, we dis-integrated the sciences and engineering. This century we're going to put it all back together. We're going to integrate the sciences and engineering, so the boundaries between the different engineering disciplines are simply disappearing. [...] The next boundary that will fall will be between medicine and engineering, and medicine and the

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Here, this administrator suggests how disciplinary boundaries form and disintegrate, and even predicts the order of their forthcoming anticipated dissolution based on their conceptual similarity to his notion of “engineering.”

A full professor provided a different image of the relationship between engineering and other disciplines:

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.

To this faculty member, it seemed engineering was an interdisciplinary construction within science, business and design came together accomplish the task of “building things.”

These quotes suggest that faculty already think of both their specific disciplines and the broader notion of “engineering” in terms which can be understood through a boundary metaphor. In the next section, I suggest how their practice of academic engineering serves to define, recognize, resist, or reproduce engineering’s perceived boundaries.

**Boundary work**

Faculty described multiple modes of intellectual and collaborative “work” done within departments and disciplines that resulted in the focus or expansion of their local disciplinary space. A full professor described the strategic planning that a department had engaged in, and used particularly graphic boundary language in doing so:

“The categories are not so rigidly defined that there isn't flexibility here, and they overlap an enormous amount. But at the same time, you can imagine things that don't fall into those categories that you could think would be plausible for a nuclear engineering department. It was more of a synthesis process, I guess is what I'm trying to say. We looked at what we were doing, and instead of making a list of twenty-three different items that corresponded to each of the twenty-three different faculty members, we tried to draw kind of a Venn diagram that largely describes what it is that we do and how we overlap. The Venn diagram has things that overlap, and so there are faculty, when you put their names -- we've done that.”

As this participant describes, the department’s strategic planning initiative prompted members to physically draw a map of what they considered their disciplinary expertise looked like, determine the relationships between their respective work areas and their placement on the map, and subsequently to make hiring decisions based on where future faculty might be placed on the map. This quote is a particularly literal example of doing boundary work, as the outcome was a graphical representation of what was acceptable research in this particular department.

In a less direct example of boundary work, an associate professor, “Prof. A,” recalled deciding to participate in a “women in science and engineering” initiative pre-tenure and against the advice of her mentoring committee. She said:
I sort of had a vision of the kind of faculty member I wanted to be and I wasn't willing to wait until after tenure to be that faculty member. I sort of made a conscious decision that involved some risks. This is the sort of faculty member I'm going to be; I'm going to practice that now, and then later on, if it all works out, then great. Life is good. Both the university and I have decided that that was a good use of my time and a good balance. If the university said, "No, we're not going to give you tenure," then that also told me something; that this is not the right institution for me; that I should be at a different institution that would have a balance that would be more appropriate for me. That was my decision.

In this response, Prof. A demonstrates an awareness of a boundary that defines acceptable -- read tenurable -- engineering work, and describes how she decided to cross that boundary anyway because she felt it should be something a faculty member should be able to do. In this sense, she recognized and resisted a boundary that was pointed out to her both implicitly (through other faculty members' tenure experiences) and explicitly (by her mentoring committee and concerned colleagues).

By chance, I also interviewed the chair of Prof. A, who, unprompted, brought up her case as an example of how well people can “balance” (its own metaphor) different and sometimes competing priorities, in this case, a focus on topical engineering research and more education-oriented research:

[Prof. A] is a very good example of somebody in our department that's absolutely excellent at it. Personally, since I happen to be the chair, will allow her free rein unless it gets super-excessive. But she's very balanced, so she does this, she does that, she's very careful to balance things. It's difficult. [...] If no doctoral students are coming out of her activities, that's excessive. [...] Where people draw the line is very mushy, because I might be influenced... If all her colleagues are saying, "you're being too hard on her. She's graduating a doctoral student every couple years, she's doing a great job and she publishes here." Then what is my opinion relative to that?

In this example, the chair indicates how he is “allowing” Prof. A to engage in activities - education research - which might normally not be considered within her work as an engineering faculty member, as long as they do not interfere too much with her more traditional responsibilities of graduating doctoral students and publishing in engineering research journals. In this case, the boundary of engineering is both reified by such boundary objects as PhD students and certain kinds of journal publications, and made porous to encompass non-traditional areas. This faculty member also acknowledges that how the “line” of acceptable academic engineering practice is “drawn” is “mushy,” more metaphorical language describing characteristics of a conceptual boundary of engineering.

A final example of boundary work is evident in one full professor’s description of some work he was interested in doing earlier in his career:

They would say, again, this was years ago, "We're looking for you to do the classic research, publications, graduate student production, more research and just keep that going as an infinite loop." And I was saying, "No, I think I'm going to try to do less of this stuff and more of what they would call 'do-gooder engineering' -- and I think they would use the word engineering,’ but I'm not 100% sure -- 'do-gooder,’ and maybe they'd spit out the word 'engineering' at that point just to kind of maybe kind of have me realize they didn't like it. But anyway, that to some extent did happen.

So this faculty member's experience was that some of his research interests that focused on, for example, making cheap and effective water filters for communities without clean water, firstly was disparaged as "do-gooder" engineering, and secondly would not be considered appropriate research to be doing at a university. Ironically, after receiving tenure, this faculty member reaffirmed this boundary for the junior members of the department:

Oh, there's no way I would urge any of my junior colleagues to touch this stuff. [...] To me this is, the future of engineering is more dependent on this, to me, than more technology. Both are important, but just the weighting that I see in this, in the profession, I need to be doing this, I guess, to kind of counteract some of the technicism (sic) that is being pushed. But there is absolutely no way that I would get tenure on this basis. There's no way that I would, I don't even urge my junior colleagues to get involved in [...] any of these sort of oddball -- I'll call them that -- courses. They should do the classic stuff because that classic stuff is what tenure is all about. That tells me there's a disconnect here. It should speak to a disconnect. But they're not, a junior colleague should not fight the disconnect. That's the job for a senior faculty person like myself or whatever.

Although the concept of tenure is ostensibly to permit faculty members the academic freedom to explore what might be considered by some as “oddball” ideas, this quote suggests that occasionally it has the opposite effect. This faculty member recognizes the boundary-defining event of tenure for those junior colleagues, and, in a sense, reinforces it through advising colleagues to steer away from “oddball” engineering, despite the fact that this individual personally values it, and believes that academic engineering is doing itself and the world a disservice by overlooking it. This quote particularly demonstrates the intertwined nature of individual action with organizational structure.

This section described the ideas of boundary language and work and provided some illustrative quotes from faculty members. The next section argues that the boundary metaphor can be used to make visible the gendered character of engineering.

**Gendered Engineering**

The second research question for this paper focuses on how engineering faculty members' descriptions of engineering can be understood through an analytic lens of gender. The conceptual tool of a boundary can aid in this exploration as the idea of a boundary denotes zones of inclusion and exclusion, and the consideration of a “boundary” in analyzing the discipline of engineering makes one look for what areas are included from those that are excluded. This section introduces two sets of quotations from two participants observing how one “thing” (discipline or idea) is different from another; in each, consideration of what is included and what is excluded makes visible the gendered boundaries of engineering. These particular quotes address a few of these participants’ thoughts
on engineering’s historical development, and the “problems” engineers have tended to focus on, both of which are structured by dichotomies of “work” and “home,” as well as “paid” and “unpaid” work. A broader organization of additional themes is addressed elsewhere [29].

As an example of the impact of history on engineering’s disciplinary boundaries: a full professor selects the case of textiles to indicate the versatility and topic breadth of the study university is saying:

“I’ll give you an example that’s very old fashioned, is that the Textiles Department, in the School of Human Ecology, I could go to Purdue, maybe Penn State, I don’t know where, and that might be in the department of Engineering. It’ll be called Textiles Engineering. That’s an old fashioned example, but that’s what my point is.”

When I inquired as to why the case of textiles might be considered as “old fashioned,” this participant continued:

“Because now people would go, “Phh, come on.” [...] Why would that even be using the word “Engineering” on that? In some schools, long ago, that was an Engineering field. [...] It has to do with the history of the culture of the university.”

This seemingly coincidental selection of textiles as an example of how history determined where disciplines should be administratively situated within a university is particularly interesting from a gender perspective. Schools formerly identified as “home economics” have been renaming themselves “human ecology” (another example of boundary work) which was one of the original names suggested during the formation of the discipline [17]. So, at this participant’s university, the topic of textiles is located in a school overwhelmingly populated by women, as compared to other universities, where it is located in a school overwhelmingly populated by men; the reason for this institutional difference is apparently, “simply the history of the culture of the university.”

This reasoning seems most unlikely, particularly in the context of the second quote. Implicit in the “phh” is a wealth of assumptions about what others define engineering. Engineering is not home economics. The participant’s scorn for the comparison can only be understood by recognizing how the two disciplines are differently gendered, how men’s work differs from women’s work, and how women’s work has systematically been historically devalued. A gendered boundary can be argued as separating these two disciplines.

In a different example, a full professor argued that people who study work processes within engineering have tended to focus certain problems exhibited by paid work rather than unpaid work, even though unpaid work was “still work.” This participant said:

“[W]e should be studying home engineering as a contrast to industrial engineering, because the home is becoming a nexus of work and citizenship and health management and leisure, and that there are aspects of that enterprise that are not aesthetic, but in fact are responsive to engineering concepts. Could be done better, safer. The artist who works at home without ventilation needs an air quality engineer to help work with them. The family who’s got a person who needs to be lifted in and out of bed needs an ergonomics person to help them understand how to... [...] I’m saying you need to know the bed can’t go that close to the window or else you’re going to dump Dad out the window. That type of stuff.”

In some rather explicit boundary language, this participant argued that the boundary was changing between home and work, and between paid and unpaid work:

“Because society is shifting, and society used to have a cleaner division between paid and unpaid work. [...] Now, with the blurring of paid and unpaid work, and the large amount of societal goals being met through unpaid work, like education or health care, we need to be bringing engineering talents into those people’s, to assist them in accomplishing purposeful goals.”

These are particularly illustrative examples, not only because of the boundary language being used (“becoming the nexus”, “shifting”, “blurring”) but also because the argument calls for a redefining of where “work” worthy of engineers’ attention occurs. Domestic work in the United States as across much of the globe [24] continues to be done more often on average by women than men. These quotes suggest that, as women have entered certain areas of the paid workforce, they have become the beneficiaries of engineering solutions. However, it is still questionable whether work which remains unpaid and is situated in domestic contexts should count as engineering - the latter quote suggests that it should do so when it supports paid work. In this case, the gendered boundary, “blurry” though it may be, seems to differentiate industrial from domestic contexts using notions of paid and unpaid work.

This section has provided two examples of how a boundary metaphor - one defined historically, and one defined between paid and unpaid work -- can help reveal a gendered dimension to our definition of engineering.

STUDY LIMITATIONS

This research is qualitative and intended to develop a theory about disciplinary boundaries in engineering and gender. It is case-based, with 10 individuals selected from across one school of engineering at one university. Choosing a small sample makes possible the use of rich descriptions of the ways that a metaphor of boundaries could be used to understand a small group of engineering faculty members’ experiences of doing their daily work in an academic context.

Future work might entail broader data collection and analysis from different sized schools, with different lengths of programmatic history, and different ways of evaluating research. It will also explore students’ interpretations of what engineering is as determined from their interactions with engineering faculty and their experience in engineering courses.

CONCLUSIONS

This paper describing the boundary metaphor is intended as a “tool to think with” [30] to consider women’s persisting underrepresentation in engineering in a different way, one where both “gender” and “engineering” become interrogated categories of analysis. The data included in this paper suggest...
that employing a metaphor of boundaries can indeed help make visible the gendered nature of engineering.

Ultimately, the act of recognizing and making explicit the metaphors that we use -- often unconsciously -- can help us think about how we construct both "problems," and "solutions." Built into the metaphor of a "boundary" are ideas of "inclusion" and "exclusion;" understanding and harnessing this metaphor can help us see how we as engineers and engineering educators use language to exclude or include ideas and perhaps people. As a profession we need to understand where we functionally (albeit unconsciously) draw these different borders of exclusion, so that we can begin to see how our actions as educators help to define, reproduce, or resist them.

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