



Into the Pipeline: A freshman student's experiences of stories told about engineering

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Into the pipeline: A freshman student's experiences of stories 'told' about engineering

Abstract

There is a growing recognition of the impact of messaging on attracting and retaining a diverse student body in engineering. Drawing on the notion of autopoiesis from systems theory, this exploratory study examines a non-traditional, freshman college student's experiences of how messaging or, stories 'told' about engineering, function to privilege and perpetuate certain understandings of the field. Autoethnographic techniques are used to construct three accounts of the student's encounters with an upper level administrator, various members of faculty, and an academic advisor. Critical analysis of these experiences using a prior evidence-based model of stories 'told' about engineering in the public discourse reveals tensions between the freshman student's values and career interests and the emergent, dominant discourse he observed in his undergraduate program. These tensions are described in terms of: i) The prioritization of national economic recovery and growth over the life and career goals of individuals; ii) A predominant focus on the quantitative and technical aspects of engineering practice over qualitative and social aspects; and iii) A 'production mindset' that gives precedence to quickly generating a large number of engineering professionals to inject into the workforce over recognizing the broader educational aspirations of students. We argue that the definitions of engineering that emerge across these conversations do not do justice to the diversity of student experiences of becoming, and wanting to become, an engineer. Based on these findings, we invite university administration, faculty, and staff to critically explore implicit messages that are communicated to students in order to be able to better respond to the diverse priorities and values students bring to their education and carry throughout their professional development.

Introduction

Times have changed. There is a new message emerging. The future of engineering, and some would say of society, depends on its delivery. The new message starts with the recognition that engineering design is a social and humanistic field, as well as a technical and scientific one; and that, like other professions, human impact is placed at the center of the process^[1].

This excerpt is taken from Diane Rover's *Journal of Engineering Education* Academic Bookshelf review of the National Academy of Engineering's (NAE) *Changing the Conversation* report. The conclusion of Rover's article, much like the report she reviews, is clear – "in an age of 'messaging'", messages have the power to transform engineering education.

A theoretical basis for the transformative power of messaging, or "storytelling" as we describe in this paper, can be found in systems theory. In the 1970s biologists Humberto Maturana and Francisco Varela coined the term "autopoiesis" to describe systems that reproduce themselves, systems that are *auto* (self) *poietic* (making)^[2; 3; 4]. Autopoiesis theory was originally conceived as a way to describe the physically bounded, biologically-networked, and self-organizing nature of life. The theory has since been applied to social systems^[5; 6; 7; 8]. In this context, Niklas Luhmann argued that instead of biological networks, "social systems use communication as their

particular mode of autopoietic reproduction” (p. 3) As leading systems theorists Capra and Luisi^[9] described:

[Because] *communications recur in multiple feedback loops, they produce a shared system of beliefs, explanations, and values – a common context of meaning – that is continually sustained by further communications* (p. 308).

Applying this theory to systems of higher learning, we argue that the social life (or “culture(s)”) of engineering colleges and departments is maintained by a network of communications from which messages or stories emerge that reflect this “common context of meaning”. What, then, are these stories? How do they emerge? And how are they perpetuated?

In this paper we examine these questions from the perspective of a non-traditional undergraduate student’s experience of stories about engineering that were ‘told’ to him during his freshman year. More specifically, we use autoethnographic techniques^[10; 11] to construct rich accounts of three encounters that the first author of this paper, Michael, had during his first year of university where, we argue, he was ‘told’ versions of stories about engineering that we have previously identified to dominate the public discourse^[12]. We use single quotation marks around the word ‘told’ to highlight the emergent and, as such, unintentional nature of these acts of storytelling. Put another way, we propose that the institutional level discourse examined in this paper is nested in larger communication systems, such as the public discussion around engineering, that shape, bound and reflect the interactions of individual actors in the educational setting.

Theoretical Framework

This paper draws on a narrative model from a prior study^[12] as a theoretical lens through which to analyze Michael’s experiences as a freshman engineering student. This model (see Figure 1) was developed using Narrative Policy Analysis (NPA)^[13], a specific methodological approach designed to examine the stories that underpin complex, uncertain, and polarized policy issues.

In our prior work^[12], we argued that the challenge of transforming the system of engineering education so that it might become more accessible and attractive to a diverse range of students fits Roe’s definition of a complex, uncertain, and polarized issue that is of broad public interest. In Table 1 we justify this claim with reference to relevant literature.

Table 1: Diversity in engineering as complex, uncertain and polarized in terms of the definition by Roe^[13]

	Definition	Example characteristics of the discourse around diversity in engineering
Complexity	“... the issue’s internal intricacy and/or its interdependence on other [...] issues” (Roe, 1994, p. 2).	Recent studies discuss the complexity of diversity in engineering in terms of the “intersectionality” of race, class, and gender and how these aspects manifest at both an institutional and individual level ^[14; 15; 16; 17; 18; 19; 20] .
Uncertainty	“... a lack of knowledge about what matters” (Roe, 1994, p. 2).	In spite of an enormous and sustained commitment to diversifying engineering ^[21] , the field continues to be dominated by a predominately white, male, and privileged population with a preference for objective, convergent, and quantitative thinking ^[22; 23; 24] . In light of the persistence of this issue, we argue that the engineering education community is

		uncertain “about what matters”, both in the sense of <i>why</i> this problem matters (e.g. is diversity a question of equity and ethics? Or putting together a more diverse and thus competitive American workforce?) and <i>how</i> to address the problem (see discussion of polarization below).
Polarization	“[that which] crystallizes... the concentration of groups around extremes in the issue” (Roe, 1994, p. 2).	In the face of this uncertainty, efforts to increase diversity in engineering have crystallized around various, sometimes conflicting, strategies. One example of this polarization are initiatives that focus on making math and science “fun” for young girls and/or youth with different racial and ethnic backgrounds versus other measures that focus on the “making” aspect of engineering to attract students. In contrast, the NAE is seeking to present engineering to young people as a humanitarian and emotionally satisfying career choice ^[25] ; while a much smaller set of voices ^[26; 27; 28] contend that the burdens and opportunities for change also fall to engineering educators.

In considering the process and findings from an NPA study, it is important to clarify that the “policy” in NPA does not imply the analysis of policy documents. Rather, Roe^[13] argues that the stories that underpin, inform, and drive our efforts to solve complex, uncertain, and polarized problems are “a force in themselves and must be considered explicitly in assessing policy options” (p. 2). In this paper we build on our prior work and conceptualize this “force” as the autopoietic function of stories, that is, the tendency for stories to reproduce themselves (and the systems that support them), systemically resist efforts to change them, and shape educational realities by being continuously told, re-told, and enacted.

Data for our prior study included one year of the American Society for Engineering Education’s (ASEE) *First Bell* newsletters (n = approximately 6,500 online news articles), which were analyzed for dominant, counter- and nonstories. These three types of stories are defined by Roe as follows:

1. Dominant stories are those stories that underwrite and stabilize the assumptions for decision making in situations of high uncertainty, complexity, and polarization. Dominant stories conform to the conventional definition of stories in that they are recognized as either scenarios, which have beginnings, middles, and ends, or, arguments, which have premises and conclusions.
2. Counterstories are alternative narratives that run counter to the issue’s dominant narratives.
3. Nonstories typically take the form of circular arguments or point-by-point criticisms of other, more conventionally structured scenarios and arguments. As such, nonstories do not have elaborative elements or conclusions and thus do not conform to the conventional definition of a story. Given that nonstories often exist only in their opposition to dominant stories and based on their lack of independent conclusions, nonstories typically do not offer a suitable basis upon which to effectively address the issue at hand.

In our analysis we identified five dominant stories, one counterstory, and one nonstory (see Figure 1). As illustrated below, the five dominant stories all share a common premise, which relates to how a chronic shortage of engineers is threatening America’s economic recovery, growth, and international competitiveness. The counterstory, in contrast, is based on the understanding that today’s students want to make a difference. This story thus concludes with calls to explore how the desire to have a positive impact needs to be incorporated into

undergraduate engineering programs. Finally, the nonstory questions the premise underlying the five dominant stories through arguing that, in fact, America is not currently experiencing, nor is on track to experience, a widespread shortage of STEM professionals. .

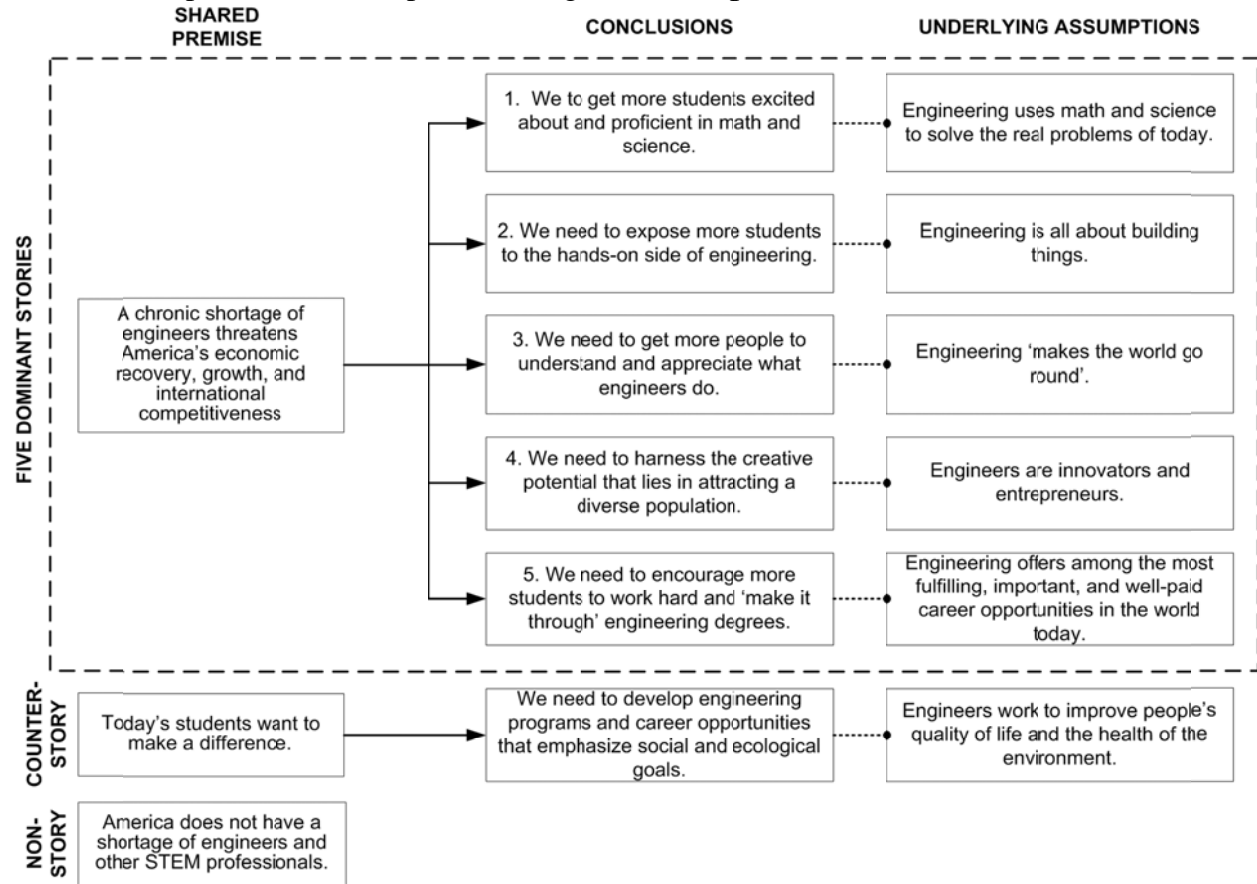


Figure 1: Narratives ‘told’ about engineering in the public discourse

Methodology and Methods

Autoethnography

Autoethnography (a combination of autobiography and ethnography) is a qualitative approach to research and writing that “seeks to describe and systematically analyze personal experience in order to understand cultural experience”^[10]. In this paper we use autoethnographic techniques to situate Michael’s experiences as a freshman engineering student in the context of engineering programs that, we argue, are in turn nested within and connected to larger social systems and discourses. Three anecdotes are presented, each followed by a critical analysis. In line with Ellis et al.’s^[10] discussion of the need for autoethnographies to be “aesthetic and evocative... [and] illustrate new perspectives on personal experience... by finding and filling a “gap” in existing, related storylines” (p. 276-277), the anecdotes present Michael’s feelings, impressions, and doubts in “real time”; while the analyses that follow apply the theoretical lens to the subjective experiences with the goal of illuminating certain features of engineering culture that may not resonate equally with all students.

Methods

This paper emerged in the context of the prior study described above. Specifically, Michael was closely involved in the latter parts of the analysis of the *First Bell* newsletters that led to the development of the narrative model presented in Figure 1. As the research team worked on this project and each of us became increasingly familiar with the dominant, counter- and nonstories in the narrative model, we found that we could not help but begin to notice these stories in our daily lives, both as engineering educators/researchers and, in Michael's case, as an undergraduate engineering student. From these observations, it appeared that the stories we had identified were indeed present in, and did seem to have a tangible influence on the engineering education context. To explore these anecdotal experiences further, Michael proposed to critically examine a small number of encounters he had had with various members of his college in his freshman year.

To begin this process, Nicki and Jo guided Michael in reflecting on and writing about five transformative moments, or as Ellis describes in the context of autoethnography ““epiphanies” [...] perceived to have significantly impacted the trajectory of”^[10] p. 275) Michael's developing understandings of engineering during the first semester of his freshman year. In the context of weekly 1-hour meetings, which took place over the period of about one year, we selected three of the five encounters, the combination of which we collectively decided, i) provided insight into how autopoietic stories about engineering function to “shape and reflect”^[12] communications at an institutional level, and ii) adequately captured and reflected the emergent nature of stories that Michael heard about engineering during his first semester of college at UGA.

Two of the three encounters (presentations given by the upper-level administrator and the environmental engineering professor – see anecdotes 1 and 2, respectively) took place in the context of a freshman environmental engineering seminar. With the aim of making these presentations available to absent students, both presentations were video-recorded and uploaded to the online e-learning commons for the class. These video recordings were also later used by Michael to complement his own recollection of the events. The third encounter, with an academic advisor, was reconstructed from personal notes that Michael took during and after the meeting.

The written anecdotes, analyses, and the majority of the discussion section presented below were conceptualized and written by Michael with guidance on structure, voice, and intended audience from Nicki and Jo. The *Introduction*, *Theoretical Framework*, and *Methodology and Methods* sections were collaboratively written by the entire research team with particular attention given to Michael's professional development as a qualitative researcher. The written anecdotes and analysis sections underwent numerous iterations. In particular, we spent a great deal of time considering how best to balance Michael's immediate, visceral reactions to the experiences with the need to be constructively critical and respectful toward the members of our college involved in the anecdotes.

Research quality considerations

Drawing on the research Quality Framework proposed by Walther, Sochacka, and Kellam^[29], this challenge can be understood as negotiating a balance between Theoretical Validation, as the need to authentically represent Michael's lived experience, and Communicative Validation, as the desire to productively communicate the meaning drawn from the accounts to engineering

educators (including the participants of this study). This key feature of our quality considerations is explored in the following description of one particular analytic decision that illustrates the character of our shared process of meaning making.

In response to feedback from “Dr. Jacobson” (see second anecdote below), we spent almost an entire meeting debating over whether or not to describe the upper-level administrator’s watch as: a) “flashy”, which was Michael’s original, immediate observation and visceral reaction, b) “what looks like an expensive watch”, or c) to simply leave this part of the story out altogether. Those in favor of option “a” felt that it was important to highlight the difference between Michael’s prior life experiences and the level of privilege that such watches represent to him. At the same time, we all agreed that the use of the word “flashy” served to set the anecdotes as immediate reactions captured in Michael’s natural voice apart from the other more formally written analytic sections of the paper. That said, those in favor of options “b” or “c” did not want to risk getting our reader(s) offside with what might be judged to be a flippant remark, not to mention wanting to avoid the risk of offending the high-level administrator in question. We ultimately decided that Michael’s authentic voice should be preserved and directed considerable care in other parts of the manuscript towards clarifying to the reader our intentions behind presenting the accounts. All three of the anecdotes and analyses were subjected to this critical, iterative, and collaborative (i.e. involving both the research team and input from the other parties involved) process of questioning and revision.

Ethical considerations

Data for this study entails Michael’s retrospective reflections on and systematic analysis of three encounters he had with various members of his college during his freshman year. It is important to point out that at the times when these encounters took place, Michael had not yet begun working on the research project described above^[12]. In other words, the encounters took place in natural settings and were not influenced or prompted by the goals and purposes of this study.

As described above, the purpose of embarking on this exploratory study was to examine how stories ‘told’ about engineering in the public discourse influence, or “shape and reflect”^[12], communications at an institutional level. The focus of the empirical analysis was therefore not the stories that individuals ‘tell’ about engineering but, rather, their relationship to the dominant, counter-, and nonstories we identified in our prior analysis of the public discourse^[12]. That said, we are acutely aware that the anecdotes and analyses below do concern real people. In order to approach this aspect of the study in an ethical manner and minimize any risks to those individuals discussed in this paper, Nicki, Jo, and/or Michael have shared this paper with the relevant parties, collaboratively addressed any issues of concern (see above), and sought permission for it to be presented at the ASEE conference and published in the proceedings.

Structure of the remaining paper

The remaining parts of this paper are structured as follows. First, Michael introduces himself. This biographical information is included to provide the reader(s) of this paper with the background necessary to understand Michael’s later autoethnographic observations and analyses. Next, Michael describes three experiences he had during his first semester as an undergraduate engineering student, each of which comprise a ‘real-time’ account of, and commentary on, a specific encounter with a member of the College of Engineering at the University of Georgia

(UGA), followed by an analysis that draws on the narrative model described above (see Figure 1). Finally, in the discussion section we explore implications of this work for engineering education.

Biographical Context

My name is Michael Brewer. I am a White, 24-year-old environmental engineering student. I enrolled in engineering at UGA as a “non-traditional” freshman student because of my GED certification and “delayed entry” status.

When I was 17, my family moved to another city and I stayed. I dropped out of high school to work full time at a retail chain. As my wages rose over the course of a few years, I discovered that the increase in income stopped contributing to my satisfaction with life at a surprisingly low threshold. My job felt like one of those that’s “just a means to an end”, but I had no particular end. At the age of 20, a friend encouraged me to go to college. As an adult, I had never seriously considered college as an option; none of my family had gone to university. The idea appealed to me the more I thought about it, though, and so I sat my GED and passed. I sold most of my possessions, dropped to part time at work, and enrolled in college the following January.

Because I was late coming to college and did not have a high school diploma, the state required me to spend at least one year at a small junior college before I could enroll in the university system. At the time I didn’t know for sure what I wanted to study, but I knew I was on the right track by starting college.

After completing my required entry year, I still needed to build up a transcript that would get me into a larger school. To this end, I spent a semester at a small state university as an applied mathematics major. While I was there, a friend told me that I should just study engineering since “that’s basically what engineering is – applied math”. I checked the Bureau of Labor Statistics’ website and found encouraging data on employment opportunities and starting salaries for engineers.

I considered engineering programs at two large in-state universities – one with a more traditional, technical program and another (UGA) who described their program on their website as “Engineering in a liberal arts environment”. This somewhat surprising take on engineering appealed to me as I have always been broadly interested in the humanities, in particular anthropology and linguistics. I was also excited at the prospect of being able to study Spanish again, which I was exposed to early on growing up in a predominantly Hispanic town in the Southwest. I was also intrigued by the descriptions of the various programs of study on UGA’s website, which talked about the broader societal and environmental implications of engineering. I had not considered at this point that I might be able to reconcile my personal commitments to social change and environmentalism with a professional career in engineering. I was excited at the possibility of living this part of myself in my career, not just as an off-the-clock pursuit. I applied to UGA, was accepted, and chose environmental engineering as my major.

In my first semester I embraced the liberal arts promise of the program and took an upper-level Spanish course alongside my math and engineering classes. In the freshman environmental

engineering seminar I learned about “humanitarian engineering”. Part way through the course my peers and I asked our professor if he could invite someone doing work in this area to come and speak to us. Two weeks later we were introduced to a professor who works on development projects in Africa. The nature of his work was immediately appealing to me, and I decided I was going to become a humanitarian engineer. I still do not have a very clear sense of what this career path would look like in practice, but I’m committed to finding out.

About half way through my freshman environmental seminar, my professor, Dr. Walther, asked me if I would be interested in working on a research project in engineering education. He described a study of media representations of engineering that he was working on with his colleague and told me that they were looking for a student who would like to help with data analysis. I agreed, and attended his research group’s next meeting. I was initially intimidated by working with professors on a research project, but I quickly became comfortable after help and encouragement from my supervisors.

My participation in this research group formed the context for the present investigation. Drs. Sochacka and Walther encouraged me to approach them with any ideas I might have for my own research project, and after being introduced to the methodology of autoethnography I decided to apply our prior work to my own experiences.

Stories I heard about engineering in my freshman year

A story about blue chip industry, technological progress, and economic growth in post-GFC America

Anecdote #1

A high-level administrator from the College of Engineering enters the classroom wearing a suit and a flashy watch. The chatter dies down as our professor stands to introduce him.

We are all freshmen, and this course is the first in the Environmental Engineering degree program. As the administrator begins his talk, it’s clear that he is well accustomed to public speaking. He is cheerful and personable as he introduces himself and talks about the history of the college.

After introductions, the administrator outlines the points he will cover in his short speech. The first one is very familiar:

“One is to tell you a little bit about why it’s a good time to be an engineer, and why you chose wisely when you decided to study engineering.”

I’ve heard this reasoning many times before. I see a new “salaries by major” report every few months or so on news sites. I also often hear them discussed by professors or friends (usually friends in the higher-paying majors). In a similar manner the administrator explains:

“Employment [for engineers] is good. Another good thing, you might have seen it a couple weeks ago, there was a little bar graph where they had the starting salaries of

different majors, and I'm proud to say that engineering was the highest on that list, significantly higher than business, which was second on the list."

As I listen I wonder about the administrator's choice of the word "proud". Is it the kind of default pride that one isn't expected to justify, like hometown pride, or pride in our major? Or is it something that we as a profession have reflected on, and have thoughtfully arrived at the conclusion that engineers well deserve our "significantly higher" salaries? As I'm struggling with these thoughts the administrator answers my question for me:

"Engineers are very important to our economy. Engineers create new companies, they create wealth, they create new jobs."

The "economic hero" rhetoric doesn't land with me, and my reaction is personal. If engineers are very important because they create companies and "wealth", then what is an engineer whose primary concern isn't economic growth? This is more than a philosophical point for me. My personal career plans not only take me away from service to "our economy" but put me squarely in opposition to the values I'm hearing described by the one of the highest level administrators within my college.

Of course, I expect to encounter worldviews very different from my own and don't assume that mine are more valid. But I am wondering whether the story the administrator is telling also allows for other versions of becoming an engineer. The story doesn't demand outright that I conform but there is a tacit hostility in the way other points of view are unacknowledged and excluded, like the feeling of dismissal when somebody doesn't take the trouble to learn your name.

After telling us about our importance to the economy, the administrator then tells us how exactly we are important:

"The role of technology, and the infusion of technology in our society, has just become limitless, right?"

To my mind, these comments even seem to imply where we will be important. From mentions of a nearby Caterpillar manufacturing plant, as well as Siemens and GE, I gather that our intended goal is to work in traditional engineering manufacturing or production. I know that some of my classmates envision that sort of career for themselves, but I most certainly don't, and surely there are others like me, right?

Critical analysis

The story of engineering as told by the upper-level administrator is founded on the Premise for the set of five dominant stories identified in the narrative model (Figure 1). More specifically,

this premise speaks to the role that STEM fields, especially engineering, play in ensuring America's economic recovery, growth, and international competitiveness.

The story of engineering as told by the administrator is the story of blue chip industry, technological progress, and economic growth in post-GFC America. The story is structured similar to the popular understanding of the engineering process; there is a problem, and a solution.

The problem is a struggling economy. We, young engineers in-the-making, are the solution. This view on engineering is a clear manifestation of the Premise ("A chronic shortage of engineers threatens America's economic competitiveness") identified in the narrative model, in that it is presented as unquestioned and self-evident. From my perspective, this inflexible presentation of the "problem" excludes students from taking part in defining their own purpose as engineers. For students who have yet to reflect deeply on their role in society, such a definitive presentation of what issues are important could give the impression that their duty has already been assigned to them, and that they will not be consulted further on the matter. Alternatively, some students might have well-defined aspirations that don't harmonize with the privileging of "the economy" over all else. Such students might question whether their professors and administration are willing and able to support those aspirations.

The administrator also gives the impression that there is a particular kind of economic growth that engineers will work in service of. Consistent with definitions of economic health identified in the narrative model, the mentions of our potential future places of employment are all blue chip giants in the industrial and technology sectors, including Caterpillar, GE, and Siemens. The administrator does not discuss career opportunities in the public sector, nor more socially oriented, or humanitarian types of engineering work.

The Great Recession, however, isn't just presented as a problem at the national level; the story of how engineering will save the economy goes hand-in-hand with the story of how entering the profession will save students from their own personal financial insecurity, and this theme is reflected in the administrator's talk:

"It's a good time in our country to be an engineer. If you follow the news and the national dialogue, you know the last few years have been difficult economically for the United States, we've had what's now being called the Great Recession, right? But [...] it turns out engineers have actually fared pretty well the last few years. There are certain degrees and certain business that haven't."

By suggesting that our quality of life is vulnerable to a fickle market, stories of this nature present the engineering profession as a safe harbor for those of us who want to make "the right

choice” and have a consistently high salary. In line with Dominant Story 5 in the narrative model (“Engineering offers [...] well-paid career opportunities”), this is the administrator’s only specific mention of what our motivations as engineers might (or should) be. As with the characterization of engineers as economic drivers, this could come across as a limited interpretation of the personal reasons students chose to study engineering.

While I often hear some of my student colleagues in environmental engineering speak optimistically about their future financial security, there are also some of us who believe that we have good work to do in the world in the service of others. In my current experience as a sophomore student, I know of few students who chose to study engineering for no other reason than “difficult economic times”. The message of financial reward is framed in a positive way, as praise for being sensible and responsible; but if it doesn’t happen to resonate with all students, it’s possible that they may not appreciate their more idealistic visions being mistaken for a shrewd investment.

A story about data points and downloads

Anecdote #2

Four professors representing the core faculty of the Environmental Engineering major are introducing themselves to the freshman class and talking about their courses and research areas. The first to speak, Dr. Jacobson (pseudonym), is a solid waste specialist – a self-proclaimed solid waste enthusiast. The first slides of her PowerPoint are pictures of interesting garbage cans from around the world, with text describing her interest in systems thinking and community involvement, the principles that ground her work.

Dr. Jacobson’s excitement for her research is contagious, and also unique. Many professors try to convince you that what they do is a hugely important and self-sufficient approach to life, like my calculus professor who insists that “deep down, everything is math”. But Dr. Jacobson, while passionate about a specialized subject, is very concerned with its place in the bigger picture; ultimately she wants to know how to better serve people.

After talking about the design courses she teaches, Dr. Jacobson presents two of her current research projects. The first is a mobile app for citizens to report marine debris found on beaches. Users can send the type and amount of waste found to a database. The second project is a “smart recycling bin”. A sensor counts the number of items deposited and, again, sends that information to a database.

“Here we have over 200,000 data points and over 10,000 downloads of this app, so it’s been very successful.”

Data points? Downloads? The mobile app is cool, but I wonder why its success is presented as “10,000 downloads” rather than “10,000 people who were given the tools to participate with experts in caring for their beaches.” Is this sanctimonious hair-splitting on my part? I don’t think so, because Dr. Jacobson let us know early on what she really cares about. But the focus on people and communities she spoke of in the beginning has been eclipsed by gadgets and numbers. The rest of her 15 minute presentation follows a similar tone.

Later, as I read the blog on her research group’s website, I learn of Dr. Jacobson’s very personal motivation to empower everyday citizens to participate in the environmental issues that affect them. This is what I look forward to learning about when I take her class in two years, but it was not the takeaway from her talk.

Critical analysis #2

Dr. Jacobson’s presentation of her research projects focused heavily on quantitative data and the use of technology to gather it. Although the waste management systems she studies are inseparable from their social context, there was limited discussion of the human side of the system.

Dr. Jacobson is obviously aware of the interconnectedness of society and technology. In fact, it is clear from her research group’s website and blog that she holds social good and environmental sustainability as paramount (see the Counterstory in Figure 1 – “Engineers work to improve people’s quality of life and the health of the environment”).

Because of this, it struck me as odd that her presentation to our class leaned so heavily toward the technical side of the sociotechnical system. Dominant Stories 1 (“Engineering uses math and science to solve the real problems of today”) and 2 (“Engineering is all about building things”) of the narrative model presented above can help explain this. The Dominant Stories, as the name suggests, dictate the terms of our conversations about engineering in society. They limit the ways we communicate and the language we use, to the exclusion of other points of view.

The focus of Dominant Story 1 is the relationship between engineering and “math and science”. This story’s argument is that “Engineering uses science and math to solve the real problems of today”, reflecting the underlying assumption that engineering is a clearly defined domain that is fundamentally underpinned by math and science. While Dr. Jacobson is very interested in the breadth of engineering work beyond just math and science, something caused her to move the focus of her presentation toward the quantitative end of the spectrum. In a room full of her colleagues and future students, it is possible that the strength of the ‘math and science’ story influenced her expectations of what subjects were appropriate to bring up in such a setting. Perhaps, knowing that we had all already chosen to enter the engineering field, she had an

unconsciously formed image of what kind of people we must be and what priorities we must have to end up in that class in the first place.

Dominant Story 2 discussed above posits that engineering is “all about building things” and, consequently, that many students are attracted to engineering by technology and artifacts. High-tech approaches to environmental issues were a key theme of Dr. Jacobson’s talk. When she spoke about two of her research projects, her focus was on the technology that was developed; a mobile app and a “smart sensor” recycling bin. In the case of the mobile app, the crowd sourced nature of her marine debris project offered a clear opportunity to talk about the role of community involvement in solving problems. But instead of talking about people, she told us about technology and numbers.

From my perspective as an engineering student, this strong focus on the technical and quantitative aspects of engineering has the effect of narrowing the possibilities of what engineering is and what engineers can do. While this emphasis on math and science may seem appropriate and innocuous, it is interesting to consider how this message functions within the framework established by the administrator when he welcomed us into the profession. When engineering is described as “the right choice” by an administrator and later implicitly defined as essentially math, science, and technology by a professor, a picture forms that sets engineering in opposition to other professions and areas of study. Together, the two narratives have the effect of discouraging students from respecting or developing an interest in “socio” side of complex socio-technical systems.

A story about the production of engineers

Anecdote #3

As I wait outside my academic advisor’s office in late May, I consider what class I might take outside of my degree. Last year I took “Controversies in Education” to engage in debate with my peers about issues I care about, but don’t necessarily get to explore in a classroom setting in the engineering college. I enjoy being exposed to things outside my set curriculum, even if I never come back to them. It feels right to choose parts of my education rather than simply be led along a predetermined path.

I enter my advisor’s office and sit. Neatly arranged on her desk are my transcripts, a flowchart of my degree path, and a form filled in with the courses she suggests for my next semester.

I tell her that I found her photography website the day before and I liked her work. She seems surprised, and after an awkward pause she sets aside the manila folder with my transcripts and talks at length about her passion for documenting old Southern buildings. Unfortunately her job at the university interferes with her plans for artistic expeditions.

My appointment lasted only a half hour. She is alarmed that I dropped my chemistry course last semester (I failed one of the four exams). “This throws everything off” she says; I would need to

retake it right away if I want to have all my prerequisites taken care of by next Spring. It will be tough on top of physics and calculus, but I just have to grin and bear it if I want to stay on track.

She shows me the flow chart of my degree track; the “predetermined path” I mentioned before. Ticked boxes indicated what classes I have taken and passed already. The rest of the boxes have my advisor’s notes in them: “F 2015”, “S 2016”. She’s planned out my semesters two years in advance.

Sally (pseudonym) is a very good advisor; she’s meticulous about helping students schedule classes around important prerequisites. I’ve heard horror stories about people having their graduations delayed by a year because their advisors were careless, so I’m comforted that she is on top of it. But at the same time I’m unnerved.

“I think I want to take another Spanish in the fall,” I tell her. It sounds like a random outburst. She explains to me that I might want to put that off until later; if I don’t get the math and physics right away, then I won’t be able to take statics next year. “As you know, this degree program is very sequential. If you get off track even for just a semester it could delay your graduation by a year or more. If you like, we can put you in as a Spanish minor and work from there later on.”

I reluctantly accept her reasoning and pack my schedule with math and science courses. I wonder if “non-essential” classes are a luxury I can no longer afford¹.

Critical analysis #3

In my experiences with managing my education, I have encountered assumptions that my first concerns are “staying on track” (meaning following my degree path flow chart) and graduating “on time” (meaning as soon as possible).

My experiences with my academic advisor, although generally very positive, illustrate how a student’s priorities can be mismatched with the priorities of the culture in which he or she is immersed during undergraduate education.

The narrative model can help shed light on what the priorities of that culture are. Dominant Story 5 identified by the narrative policy analysis says that we need to encourage students to work hard and “make it through” engineering degrees.

This story is characterized by a mindset that prioritizes the rapid production of new engineers. An underlying problem of retention and graduation rates in engineering majors is taken for granted as something that needs to be overcome by policy, curriculum, and messaging².

¹ In discussing this paper with the advisor (see “Ethical Considerations” above), she brought to my attention that students have the final say in what classes they register for. However, she is expected not to advise for classes that are not part of the engineering curriculum; if a student regrets his or her decision to stray off track and asks for some exception, the advisor would have to answer for why she did not advise according to the curriculum.

The language used in Dominant Story 5 offers a look into how students are conceived of in this mindset. The familiar metaphor of the “the pipeline” that carries students from primary school to the engineering profession evokes the notion of the extraction of crude material to be transported and refined into something useful and valuable. This metaphor extends to students who leave the pipeline; they “fall between the cracks”^[30].

Having been warned of such an outcome, I can’t help but wonder if prioritizing the production of engineers over helping us achieve our personal goals might, in some way, be problematic. As a student who is aware of certain conversations and campaigns geared toward keeping me “in the pipeline”, I am forced to question whether administration and I agree on to whom the university is ultimately responsible. My experiences of being pushed through a “sequential degree track” with warnings against late graduation sit uneasily alongside presentations of partnerships between my university and outposts of blue-chip industries who recruit recent graduates from within the state for internships and employment.

Examining “the pipeline” in this way, a picture of the commoditization of engineering students forms in my mind. We are treated as raw material to be secured, shaped into something economically productive, and then managed as resources in a grand national project. I have difficulty seeing how well-intentioned recruitment and retention efforts that begin from this perspective can acknowledge the diverse range of goals, interests, and motivations of students. Rather than allowing future engineers to define their own purpose, and to define the purpose of engineering, these recruitment projects seem to want to persuade us that we all want the same thing; economic growth in an America that rewards us with high salaries.

Discussion

The application of the narrative model (Figure 1) to a freshman student’s experiences suggests that the dominant stories that Sochacka et al.^[12] identify in the national media discourse are observable at the local level. As the theory of social autopoiesis suggests, these stories are constructed and maintained through “multiple feedback loops”^[9] between the media, university faculty, students, etc., and provide a common frame of reference for defining problems and suggesting possible solutions.

We have seen through the contrast of the dominant narratives with the personal values of their participants that it is not necessary for these stories to be crafted with intent; the narratives emerge through the selection of what ideas are appropriate to discuss in an engineering or

² In our discussions prior to publishing this paper, the advisor emphasized that she advises for “on time” graduation in response to feedback from students themselves. Her first concern is the health and success of students and, from her experience, most students want to graduate “on time”.

classroom context, and how these ideas come together from the students' perspective to form a coherent narrative.

Although the dominant stories are, to a large extent, formed implicitly, this autoethnography shows that the dominant narratives are created and reinforced through the participation of individuals at different levels within the system of engineering education. This has important implications for strategies to “change the conversation”^[25], which typically target those directly involved with outreach activities, rather than agents within the system of engineering education itself. The following draws on different conceptions of engineering design as a metaphor to illustrate the challenge such efforts face.

Generally speaking, the methodology of engineering is to identify a problem, study it, and design and implement a solution. This traditional approach is well suited for simple, clearly defined, linearly causal systems. In the first author's native environmental engineering, this is analogous to searching for a point source of water pollution that is impacting a fish population, such as a pipe leaking chemicals into a lake. Solving the problem is as simple as patching the pipe.

In complex social systems, however, problems are vaguely defined, and the behavior of the system is non-linear^[31; 32; 33]. The environmental engineer may never find one leaky pipe, but find instead that nitrates in fertilizer run into the lake from some nearby farms, and the water is polluted with acid rain from sulfur generated by many sources in various industries. When there is no leaky pipe to patch, patches are a poor solution.

Engineers who think they have found the point source of a single, well-defined problem will naturally try to fix the broken component or design a better part. If the problem is systemic, however, solving the problem will require a systemic approach. Good solutions will be broad, multifaceted, cooperative efforts among individuals at all levels of the system, as opposed to a single solution targeted at only one level or group of agents in the system.

To this end, we invite faculty and administration to reflect critically on the stories they implicitly or inadvertently ‘tell’ and the emergent understandings of engineering that these stories might communicate to students. Such critical introspection could support ongoing efforts to create classrooms that are hospitable to a wider range of worldviews, with the goal of developing a rich engineering culture that is receptive to diversity and change. In such settings, students who are participants in (rather than recipients of) their education would be allowed, and even actively encouraged, to take part in telling the story of engineering, and defining what engineering is and could be. If this is our goal, then perhaps the task at hand is to *broaden* (rather than “change”) the conversation and allow change to emerge from the richness of ideas and worldviews available to us at all levels of the system.

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