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"Turning away" from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class

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"Turning Away" from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class

Culture in Educational Problems

> Culture is not a past cause to a current self. Culture is the current challenge to possible future selves.
>
> Ray McDermott, in Reconstructing Culture in Education Research[1]

> There are these two young fish swimming along, and they happen to meet an older fish swimming the other way, who nods at them and says, "Morning, boys, how's the water?" And the two young fish swim on for a bit, and then eventually one of them looks over at the other and goes, "What the hell is water?"
>
> David Foster Wallace, and others

This research proposes to study the production of an educational problem: that of students deemed "not cut out for" undergraduate engineering. To understand the struggles of students and create a system that produces successful, not failing, students is at the heart of much educational research. But there are different ways of doing research, and they differ in the extent to which they treat the "problem" as the phenomenon of interest. Our research attempts to take a familiar educational problem and to grapple with it in an unusual way, by focusing on the many mechanisms by which the problem is culturally produced.

Invoking the word "culture" here could conjure for readers something other than we intend. If "culture" is associated with something more about "foreign" countries than our own, more about "unique" aspects than what is pervasive, more about the past than the present, or more owned by whichever category of "other" people than by ourselves, it misses our mark. On the other hand, we don't mean to say that culture is instead owned by the native, the normative, or the powerful. In one case we have an intellectual fascination with explaining the exotic; in the other case we risk veering towards an superficial and self-congratulating take on culture: in our nation, perhaps looking at the celebrations and traditions which make us most proud, in engineering, perhaps uncritically extolling values of "meritocracy" and "creativity."

These common sense understandings surely are pieces of culture, but they are only the static and easily visible elements that tell us what we already know about ourselves and our relation to others. Instead, consider that the vast majority of culture is the "water" we as fish cannot see ourselves swimming through. It is always present and shaping our perspective, though it is invisible; it is always affecting our actions, though we operate without needing to think about it; it is flowing and shifting around us, though it is also inherently always already there. It is much bigger and much more amorphous than the pieces of our world of which we are usually conscious, and as such it is harder, and all the more vital, to interrogate.

This paper investigates the culture, the "water," shaping the production of the educational problem of some students being "not cut out for" engineering. Drawing on the notion of cultural construction[1], this paper aims to make visible and to interrogate how the actions and interactions of many people, as well as institutional policies and societal values, work in concert to "produce" the fact of someone not cut out for engineering. In doing so, we aim to suggest an explanation that locates the cause of such problems in broader cultural practices and interactions rather than in the individual students or their own "mismatched" culture.

Literature Review: Addressing Struggling Students

Amongst the various purposes of academic research in education—to develop new pedagogical theories, to assess instructor training procedures, to incorporate new technologies into instruction— there is long-standing attention to identifying, analyzing, and remediating educational problems. Responses to educational problems can take different forms, from the theoretical (why is the problem occurring) to the practical (how can it be ameliorated). For example: educational problems of K-12 academic inequity and school failure motivate research and policy such as No Child Left Behind. In higher education, identification and analysis of problems facing first-generation college students leads to developing "bridging programs." In a broad sense, this strand of research and remediation tends to be born foremost out of a deep concern of all of those involved with the educational problem at issue.

In this paper, we take up the long-discussed problem of struggling students in undergraduate engineering programs. Responses to the problem of struggling students have been varied; the following is a coarse literature review of some responses in order to position our work.

Traditional quantitative retention research has documented the magnitude of the problem and clarified large-scale inequities in access to higher education in STEM based on gender, race, socioeconomic status (for example, Ong et al. and Seymour and Hewitt)[2,3]. This research often draws on a metaphor of the "leaky pipeline" to justify institutional remediation, including support programs for racial, gender, and (recently) sexual minorities within higher education STEM programs. Likewise retention research highlighting additional corroborating factors in student struggles, such as self-efficacy and cognitive attributes[4,5,6], has informed the efforts of some of these support programs in affective and academic dimensions. Qualitative research strands that look at identity and marginalization have documented struggles from the student perspective, noting how aspects of self can contribute to or come into conflict with one's progress and prosperity within a STEM major[7,8,9]. This research often employs a metaphor of "cultural mismatch" or "identity mismatch" to help extend the empathy and perspective of practitioners and those involved in the day to day of STEM in higher education, to consider diverse student perspectives more substantially. Additional strands of qualitative research which focus on cultural and interactional analysis have looked at higher education as a social system, looking at ways that the interactions and cultures of classrooms and institutions work (often unintentionally) to create problems for students (in K-12 science: Carlone[10]; in K-12 math: Esmonde[11]; Gresalfi et al.[12]; in undergraduate engineering: O'Connor et al.[13]; Tonso[14,15]). In this smaller body of work, we gain insight into mechanisms which create the problem of struggling students.

While we see all of these research strands as coming from a place of caring about educational problems and we recognize their practical contributions towards reform, in this paper we draw on a perspective advocated by Ray McDermott[1] to suggest and illustrate an alternative approach to research on educational problems, which he calls "turning away" from the struggling individual. More in line with interactional and cultural approaches cited above, this *cultural construction* approach looks at the ways in which many actors within a culture create an educational problem. Thus while we share the feelings of concern motivating the prior research strands, we want to question how these persistent educational problems get produced and reified, including (potentially) via well-intentioned researchers, institutions, and practitioners. We start from this common place of caring about struggling students, and in asking what can we best do to address the problem, we find that the answer may be, counter-intuitively: "turning away."

Why cultural construction?: Engineering Education in Three Cultural Paradigms

Having touched on the breadth of ways that research and institutional programming have tried to address the problem of struggling students in STEM, we now draw on McDermott[1] more directly to comment on each of these approaches and to introduce our particular approach.

For McDermott, all educational problems are cultural problems. The production of the educational problem involves many actors; those who ask and those who answer the question in academic literature, those who in practice recognize and those who are recognized as having the problem, and the many more who support the common cultural understanding of the phenomenon as a problem. To help focus the thinking in this framework, McDermott proposes a three-stage framework to take different levels of the problem into account. In Stage 1, an individual is conceptualized as having problems completely on their own; any problems identified are simple evidence of the individual's own intellectual, moral, cultural, etc. deficits. In Stage 2, an individual is viewed as experiencing problems on the basis of social structures much larger than them; and any problems identified can be explained as the natural result of having been socialized to occupy that position in society. Finally in Stage 3, the problem is viewed as being created only via the concerted effort of many actors in a culture which imbues meaning on the problem; any problems which are able to be discussed must have been noticed, measured, compared to a norm, reported, discussed, and accorded a shared meaning and importance.

Applying McDermott's framework, we can see new dimensions to many common approaches in studying the problem of struggling students in STEM. In quintessential retention research, the powers that be define the terms of success and failure (e.g., persisting in a certain major, institution, or career, achieving a certain GPA, stating a sense of disciplinary identity and efficacy), and find the aspects of students which contribute most to success or failure (e.g., gender, race, socioeconomic status, high school GPA, self-efficacy). In this research, the individual is the site, and their individual qualities are the source, of the retention or diversity problem, Stage 1. Although an institution with too many problem individuals will feel some pressure to reform, the underlying structure of this research is not to interrogate the institution, but the factors effectively "owned" by the individual. By revealing supposed flaws inside failing individuals this research can also create narratives around the expected performance of types of students which become an implicit justification for a status quo. Likewise, the remediation avenues which open up via this line of research will tend to "fix" the student via support groups, mentoring, and bridge programs aimed at underrepresented and at risk groups. While effective, such remediation efforts can blind us to the ways they do not address the marginalization and broader cultural process of producing the educational problem.

In research we term "cultural mismatch" research (for example much of the prominent identity research on gender, race, learning approach), the individual is again the site of the problem, yet not the source of the problem. The individual has been socialized to embody a certain static "culture," which comes into conflict with the norms of the institution in power--Stage 2. [Note the use of the world culture here-- as in "a culture," a unique aspect or trait of an individual. This is an intentional characterization of Stage 2 framing and one we will diverge from shortly.] While now taking into account larger forces, the cultural mismatch research often misses the ways in which many experiences of educational problems are not just "mismatches" but are systematically created events of marginalization. Likewise Carlone and Johnson[16] highlighted that the “funds of knowledge” research paradigm is fundamentally looking for cultural differences students bring from their home life rather than, for instance, the cultural production of difference in school spaces. While many approaches in this vein have a potential to create classroom experiences more attuned to individuals, they also have a potential to justify institutions as they are, since the classroom / institutional operations are never critically examined within the scope of the research.

Finally, in research which is relatively uncommon in addressing educational problems in STEM, there is work that takes a cultural analysis framework (i.e. stage 3, cultural construction, cultural production). O’Connor[13] has looked at the institutional and cultural work involved with creating and assigning the label of “Calculus-ready” for students, which in turn is viewed as a property of underprepared individuals on their own. Carlone[10] has looked at the classroom cultural production of the “science person” identity, and considered it as a form of resistance or reproduction of larger cultural meanings. Gresalfi[12] considered the construction of competence in K-12 mathematics classrooms, work done not by incompetent individuals but by classroom participants in interaction. This is Stage 3 analysis which, at different grain sizes and phenomena of interest, interrogates the ways in which many actors in a culture work in concert to produce the problems and phenomena identified. Viewing the engineering education literature from the perspective of McDermott’s three stages of cultural analysis, we note the value of complementing current research paradigms with stage-3 cultural construction analysis, in order to approach educational problems in undergraduate engineering education from as wide a lens as possible.

Why ability?: Emergent Analytic Focus

We feel the approach of examining the cultural construction of educational (or cultural) problems could loosely apply to many parallel strands of research. In the area of gender studies, several post-structuralist scholars (e.g., Judith Butler) have deconstructed aspects otherwise considered stable aspects of self (being a woman, being transgender) as social constructions, in terms of the categories, meanings, and norms an individual has agency to choose or perform. Flipping the tradition within racial scholarship of often studying a predetermined “other,” several movements (e.g., whiteness studies and critical race theory) have attempted to study that which we take for granted about race, the normative category of “white” and the creation and enforcement of racial categories across history. One could imagine then pursuing a research program organized around the cultural construction of race, the cultural construction of gender, the cultural construction of maturity, the cultural construction of criminality. In the education research reviewed above, we have seen research on the cultural construction of “science person” and “Calculus-ready.” In this research, we interrogate the cultural construction of a student as “not cut out for” engineering.

This choice emerged from the iterative nature of the research, as initial observations helped guide our theoretical framing which in turn guided further observation and thinking. In the first pilot term of the course that we examine here, only 5 students enrolled. One of the five students, Isaac (all names are pseudonyms), was much slower than the class norm (e.g., in lab programming assignments), and two students appeared to particularly excel. By the end of term interviews, the professor and other students could pick out who in particular was struggling and slow, as could Isaac himself, who reflected “I just don’t think I have the brain for programming.” This happened, in spite of the fact that programming in the professional world is rarely a timed activity with “winners” easily noticed, and in spite of the fact that the students with whom he compared himself arguably did not belong in an introductory programming class. Specifically, two out of the five students arrived through non-traditional pathways (a second bachelor's degree, a community college transfer), and the accompanying registration difficulties appeared to place them in an introductory programming class in spite of having had fairly substantial prior experience. This phenomenon of Issac being made a "struggling" student emerged as worthy of unpacking because 1) it seemed to develop from such natural classroom activities and means, 2) it seemed to have such deep effects on student self-perceptions.

What to call this educational fact? To invoke another common paradigm, this did not seem like an "identity mismatch." The student in question was apparently white, middle-class, male—to be frank, perhaps even more of a normative engineering student than the two students who arrived from non-traditional means. He was not suffering a culture clash with the educational material or environment, or at least that was not the most direct way of describing the phenomenon. He maintained an identity with engineering, was intending to persist with the major and felt he had other engineering disciplinary strengths. Though clearly he did not identify as a programmer by the end of the class, that wasn't as salient as the feeling of not being able to do it. The phenomenon we were putting our finger on was related to identity, but with more of the weight of observation and approval, less of the agency of identification. What seemed interesting was that this class appeared structured to be able to observe and confer the "worst" and "best" programmers, and in ways that seemed to surprise no one as opposed to, say, the norms of a writing seminar where all are expected to acquire the skill without finding out who is incapable at writing.

What seemed to be coming up in this interview was a daily experience of being constructed as incapable, in programming (for Isaac) and/or in engineering. We call this the cultural construction of ability, of being "not cut out for" the discipline. The disability at play in this educational fact is not one that often gets labeled or spoken out loud in those terms, though neither is it only living inside one student's head. The sort of ability hierarchies at play here have a mutually acknowledged meaning and institutional consequences. By cultural construction of ability we mean to acknowledge the many levels on which this construction occurs (in the individual perception, in the shared social space, in the institutional trajectory) and to demonstrate that they are inherently connected and reflexively produced. This phenomenon of interest became the guiding theoretical focus for the ethnographic work in subsequent semesters.

Disclaimer

There may be a temptation to shift blame from individual students to individual teachers, from individual teachers to individual institutions, from institutions to an engineering sub-discipline, etc. We want to actively resist that in our writing and in its interpretation, on the following grounds.

First, a purpose of this research is to consider how all actors are connected to the construction of this problem, and how each actor is constrained within our culture with limited agency, often actively working with good intentions, and **still** creating problems for students. Being constructed to be the "worst" student in class is the most mundane experience of any classroom, but do classes need "worst" students? This is a phenomenon we think is central to equity / representation issues in nearly all classrooms, so we are interrogating it in order to consider how it comes to be and whether there are alternatives.

Second, this is not a paper about mean students, poor instructors, or bad classes. While we resist this on the grounds that such boxing of people is also culturally constructed—we in general would like to put forward the engineering class in this study as fairly typical, and in general "above average," if one values relatively progressive pedagogy, student-centeredness, "hands on" participation, collaboration, etc. We have student survey data which suggests that most students would agree with this assessment, and that they enjoyed and valued the course. This is not to cast a shadow on traditional lecture classes as "even worse." In terms of the phenomenon of constructing this educational fact, we simply note that relatively progressive pedagogies are not spared the culturally shared practice of constructing failing students. We would like the reader to consider that the classroom in this paper may hit a bit closer to home—to see the ways many familiar classroom practices may be doing similar things.

Methodological overview

The methodological approach for this project came about via both theoretical (literature) and practical considerations. While the cultural construction literature tends to emphasize theory and analysis, we tried to assemble a robust and consistent methodological approach to investigate cultural construction in a particular setting. In McDermott's early writing at the time of his data collection (1970's) he aligned himself methodologically with three primary traditions: ethnography, ethnomethodology, and discourse/interaction analysis[17,18,19]. As an investigation of culture, the work relies on ethnographic methods and approaches, such as the incorporation of multiple qualitative data streams, ethnographic field noting[20], and one-on-one participant interviews. As a study of subtle cues and ways of operating in an everyday educational setting, the methodology also draws on ethnomethodological approaches, similar to seminal work by Mehan[20] uncovering common discourse patterns (I-R-E) in K-12 classrooms. Finally, incorporating the affordances of videotaped activities in the lab classroom, the approach draws on close discourse and interaction analysis approaches[22], whereby culture can be seen as constructing and constraining even small moments of a class interaction. In drawing on these traditions, we acknowledge that the current project is in many ways more focused (only on the cultural construction of ability) and more constrained than the idealized version of each methodology. For example, within a one-semester class (let alone in McDermott's cultural construction paradigm), there may not be a stable "culture" to embed oneself in as is the case in the most traditional version of ethnography.

In practical terms, the data collection grew out of a multi-year project to investigate a novel programming class. The course context included weekly lectures to present content mainly via PowerPoint to all 30 students, and 10-person lab sections to allow students to apply their learning to engineering tasks. The following were primary sources of data and how they were used:

- 9 student interviews were conducted pre- and post-semester, and 3 follow up student interviews during the subsequent semester. Student interviews were a primary resource to help focus the analytic gaze during the taking and revisiting of field notes and video data, to find what aspects of the class were salient to the students in producing a particular personal experience or reputation (say, of being incapable).
- Video data was taken in lab, of specific students working individually or in pairs. This interaction data was central to understanding processes of cultural construction, and had to be examined while theorizing about the culture which could have created and stabilized the interaction, and affected the meaning drawn from it. Content logging helped establish patterns over time, and highlighted episodes for closer examination and transcription. We took a more ethnographic approach of "field noting" the scene, beyond only literal transcription of speech events. In this sense video data was an extra set of eyes and ears for the ethnographer, rather than a pure objective data source to document frequency.

- Expansive field notes were taken, particularly in lecture and in moments which were not captured on video, with the purpose to provide a rich description focused on guiding questions such as: who is positioned as capable or incapable in this setting?, how is one's "ability" becoming public in this setting?, what are the consequences for participants' self-perceptions?, and what are the consequences for opportunities for learning? There are approximately 50 typed pages of fieldnotes from the semester observations. The field note documents were coded to keep track of emerging analytic themes.

The analysis progressed via assembling several analytic memos, incorporating accounts of lab interactions, field notes, and interview transcript into accounts which centered around particular students (e.g., all of one student's lab partners), cultural categories and their meanings (gender, academic status), and patterns of interaction (competition in lab, the winking admonishment of advanced student questions during lecture). These analytic memos built up towards the sections of the argument in this paper, since they tended to focus attention on aspects of the world under examination which contributed to cultural construction of engineering ability. These interpretations were continually discussed amongst the research team and with other colleagues at research meetings for considering alternative interpretations for increased robustness of the argument, via a process of iterative refinement of hypotheses[23].

Triangulation (or crystallization) of diverging data sources and interpretations was important to the analytic process; so for example, a student quote was not taken at face value but used as a guiding orientation to the holistic consideration of the dataset. However, triangulation did not mean we believe we have found the one "true" and "objective" interpretation, and the analysis did not limit itself to only that which could be determined within the bounds of absolute objective truth. Acknowledging the role of researcher interpretation in ethnography, the goal of this project was to develop a credible and compelling account of cultural construction. The fact that others could view these events and interpret them otherwise is built into the purpose and framework of the project. We know that there is a different set of common sense wisdom often at play in these settings, so we often attempt to lay out both interpretations in order to persuade the reader to consider the events via cultural construction.

Data Analysis: Three Stages of Cultural Analysis

Now we return to the educational fact in question, that of the failing or struggling engineering student, and place it in the particular context of the institutional and instructional setting in question. Stage 1 and stage 2 analyses capture two forms of commonsense wisdom which connect to theoretical perspectives on culture in education. We outline them partly to contrast them with stage 3, the theoretical perspective guiding this work, in which we "turn away" from the individual struggling student to examine the cultural construction of "not cut out for engineering.

In a Stage 1 analysis, we limit our view only to the individual, and see what understanding of the problem this affords, what solution spaces it opens up:

> ***Stage 1 - Individuals have problems because of personal failings***
>
> There is a persistent problem in introductory engineering classes where certain students just can't keep up with the rest of the class. Not everyone is cut out for engineering, not everyone has the natural intelligence, the grit, the academic background necessary for success. Certain students are struggling in this class, especially the students from disadvantaged backgrounds and groups. They ask a lot of questions in office hours, they work slowly, they seem lost in laboratory sessions. If they are struggling so deeply and

so early, perhaps they aren't going to make it. We feel bad for them and would like to help, but aren't sure how to motivate them or catch them up. Do they need extra office hours? But there's not time to help everyone, and the problem seems to run much deeper. We might think, *Poor students, but if they can't keep up with the rest of the class there's not much we can do about it.*

Our focal student, Becca, was one such student, and she, her classmates, and the professor were consistently aware of her struggles. A Stage 1 analysis looks particularly bleak for Becca: if her problems are internal to herself, she seems predestined to learn, sooner or later, that she is not cut out for engineering.

In a Stage 2 analysis, we broaden our view to see that struggling students are often disadvantaged by their different backgrounds, which are created by broader social forces. Thus we can examine whether the performance of students is affected by culture clashes with the institution, due to gender, race, and socio-economic class, among other categories.

Stage 2 - Societal forces and culture clashes produce problems for individuals.

The in-school and broader American culture is such that girls likely grew up with less computer and technology access than boys, at home and in informal learning settings[24]. This is not their fault and their background is just as valid as the men in the class. But women were notably struggling in this class, though not all women were struggling, and not all struggling students were women. Still their womanhood must be playing a role in this traditionally masculine field, and putting them at risk of not making it in engineering. *Too bad society puts these women at a disadvantage when it comes to learning traditionally masculine subjects; perhaps we can take steps to create a more woman-friendly atmosphere.*

A student's socioeconomic and high school background also matter. With fewer opportunities to study programming, students from vocational public schools often arrive underprepared to meet the norms that the institution and majority of students take for granted. This institution often admitted underprepared but committed students as "Letters and Sciences" rather than full engineering majors. This label gets printed on the roster, so professors often note how their Letters and Sciences students are struggling, less brilliant than their engineering major peers, but usually scrappy and working even harder. This lesser-known special offering class was opened up to Letters and Sciences students in order to fill seats, and because the instructor had an interest in supporting disadvantaged groups. The Letters and Sciences students were close to his heart and perceived of as struggling. Again, we might think, *too bad the students' school systems and socioeconomic backgrounds shortchanged them in their preparation to be an engineer; perhaps we should establish bridging programs for these students, but there's not much we can do once they reach my course.*

Our focal student, Becca, is female, Letters and Sciences, and attended a vocational public high school with an electrician's track, but no programming classes. In a Stage 2 analysis we are primed to identify students with these characteristics, to worry about them, to regret the world that disadvantaged them. Perhaps in a progressive, small, personalized learning environment, we could find and pedagogically build upon some of Becca's unique strengths. But programming class being a fast-paced place where some are shown to be better programmers than others, Becca looks to be substantially at risk to become the "not cut out" of the electrical engineering introductory courses.

Finally, in Stage 3 analysis, we "turn away" from the struggling student. Students do not own or bring educational problems into the classroom. Instead, the individual student is just one of many actors operating to produce and recognize an educational problem (such as "not cut out for engineering"). The individual student often has limited agency to subvert this process, constrained within a culture designed to systematically produce and notice the problem. In this approach, by analytically turning away from the individual student, we redefine our task as figuring out how the category such as "not cut out for engineering" is (re)produced in the first place and how the category "recruits" students such as Becca.

Stage 3 analysis constitutes the rest of this paper and the actual empirical contribution of this research. This kind of analysis presents a challenge both to write and to read, because individual pieces of the argument can look unimportant or even unconvincing on their own, but gain power when combined with the other pieces. McDermott[25] used the metaphor of "fibers in a rope" to help clarify that pieces (fibers) of a complex system may look meaningless unless the whole (rope) of what the fibers are working together to construct is held in mind. Yet, in order to understand the rope, we must analytically break it down to the level of fibers and re-twine it. This work is hopelessly non-linear and always leaves something else to unpack, and we hope to convey it within the scope of a short paper. In the interest of conveying the rope, we present here a brief holistic analysis, which will be elaborated more in further publications.

Stage 3 - "Turning away" towards the cultural construction of the problem
Deconstructing Social Labels
Social labels associated with Stage 2 explanations (woman, Letters and Sciences) do *not* connote fundamental traits explaining Becca's behavior. It would be more accurate to say they connote the categories our culture has attuned us all to perform, notice, and ascribe with meaning, next to dozens of other possible cultural facts and categorizations we could notice about people but don't. And in engineering classes, some categories are bound to be noticed instead of others. Simply by our (Stage 2) awareness of which categories of students are normally "at risk" in engineering, we all (students, researchers, instructors) become bound to a world wherein academic struggles are part of, or are an exception to, the common storyline of a demographic group.

In introduction to programming, it may seem counterintuitive that labels of "programming background" and "no programming background" became particularly salient. Although programming knowledge was not a prerequisite for enrolling in the course, students arrived with a wide range of backgrounds, from none to having programmed in C and Java. The normative student was assumed to have some, not extensive, programming background. As such, "no programming background" became a "deficit" category for individuals like Becca who were acquired by it.

These labels became more public in the less constrained social space of the lab, (in ways which may be widespread in dorm rooms and hallways). Becca's identity as Letters and Sciences and lacking a programming background sometimes became public knowledge in lab conversation which undermined her epistemic status as a student. Students projected and observed femininity or masculinity in the classroom, for example via jokes about stereotypical dress and social status. Since gender, Letters and sciences, and programming background also carried their own narratives and connotations of power, the constitution of the labels in the classroom discourse contributes to the construction of ability.

But the categorization of students with the associated stereotypical narratives was only the first piece of the construction of ability. Although programming background need not have become a relevant category in an introduction to programming, many subtle aspects of the course curriculum and classroom interactions constructed one's programming background as significant and preemptive evidence of one's lack of ability in engineering.

Bodies in Seats

In lecture, students' actions were more constrained but gender (always visible) and programming background were no less salient. From day 1, students were well aware that all 3 women in the class were sitting towards the rear/left of the classroom, a visible representation of a broader pattern that found students with less programming experience (both men and women) sitting towards the rear/left, while students with more programming experience (men only) sat towards the front/right nearest the projected lecture slides. This arrangement lasted the entire term.

Seating patterns began to map out and mark these dimensions of epistemic power, and they created the circumstances for differential experiences of the lecture content, fueling micro-inequities that can widen, rather than reduce, any inequity seeded by programming background. Sitting at the front, advanced students would stay in easy conversation with the professor, murmuring unofficial replies when questions were posed to the whole class. Sitting at the back, instead, requires one to draw attention of the professor and speak louder when asking a question. Thus meaningful class participation was substantially easier and less socially risky for advanced students than beginning students, and they were likewise the students the professor heard most from. This pattern seemed to sustain and be sustained by the seating arrangements divided by ability.

Although a small classroom, the physical distance from the closest to the furthest seat meant that screen text was orders of magnitude smaller for students in the rear left. This became particularly apparent in the switch from PowerPoint (which typically used font sizes appropriate for a class presentation) to code implementation (which used the default font sizes of a programming IDE). An unfortunate educational micro-inequity, since many students attest in interviews that the code implementation portion is the most useful and interesting part of lecture.

Lecture materials provide a "crash course" "introduction" to programming

In lecture PowerPoint presentations, a "crash course" approach to the first two weeks intended to give a flavor for the language before diving into specifics. However, given the pace and content-level, it was significantly more understandable by those with some programming background. An example slide from the first week Crash Course shows that by only Slide 27 (covered on the first or second day), the second example features an entire program with fairly high level content as shown in Figure 1 on the left.

If some of the terms and format here seem like unexplained jargon to those of our readers less versed in programming syntax, so it is for the student without any programming background.

```
Slide 27
/* example #02 electric field calculation
* Written by Phil
* Version 1.3 Last updated Sept 3, 2014 */
#include <stdio.h>
#define CHARGE -1.602e-19      /* new feature */
#define EPSILON_0 8.854e-12
#define PI 3.141592654
Slide 28
int main(void) {
   float e_field, radius=.0025;    /*new feature */

e_field=CHARGE/(4.0*PI*EPSILON_0*radius*radius);
   printf("Electric field at a radius %f =
%f\n",radius,e_field);
   /* this printf has more than one argument */
   return 0;
}
```

```
Slide 29
#define CHARGE -1.602e-19      /* new feature */
#define EPSILON_0 8.854e-12
#define PI 3.141592654
Pre-processor directive "define" generates
symbolic constants. Constants are replaced in
code by numeric values before compilation.
No equal sign and no semicolon
Convention for constants: use all uppercase
letters
Good programming practice: use symbolic
constants often!
```

Figure 1: Two example slides from "Crash Course" lecture material

The subsequent slides aim to break out parts of this code and add vocabulary and conceptual lessons (Figure 1, right). The explanation slide continues to use so much jargon that it would be hard for even a somewhat experienced student to follow it: "pre-processor directive," "generates symbolic constants"—what are hypothetically the explanations to the more opaque "define" terminology are in fact jargon-heavy ways to explain simple concepts. And while the intense Crash Course ended after two weeks, this sort of jargon continued to dominate the PowerPoint slides and spoken lecture content.

Instead of critiquing instruction, our purpose here is to help the reader get a feel for what a student like Becca with no programming background might experience in such an early "introductory" programming lecture. In some sense, the lecture slides function to highlight for those students their lack of background (when none was required); instead of increasing understanding, they generate anxiety.

In addition to being dense with jargon, lecture slides moved quickly and were often overwhelming for Becca, and those with less programming background. But in this matter, Phil, the professor, is also highly constrained by his position in a system: as a special course offering this class had to contend with the expectations for what students would learn from the typical introductory programming course, while offering its new content in addition. Engineering departments are often conservative in this way, as perhaps many educational institutions are—new content on cutting edge technology is welcome and encouraged, but not at the expense of any of the previously held fundamentals, particularly not ones built into the traditional course progression.

Lecture Games

The daily PowerPoint-based lecture was fun and student-centered, with high rates of participation. However, a lecture interaction pattern was sustained where high programming background students asked advanced questions only tangentially related to the current content. Some advanced students were conscious of playing a sort of game and found it amusing to distract the professor, though it seems likely that many students were asking their tangential questions in earnest. The professor worried out loud about wasting class time, but continued to be responsive to advanced student questions. Although he would often preface his response with a winking admonishment, "that's way beyond the scope of the class!," he nevertheless found himself spending significant portions of class time answering such questions thoroughly.

Given the nature of the questions (as beyond the scope of the class) only a small portion of the class understood the content of these questions and answers. Thus this question and answer session functioned as projection of ability: students noticed who had the ability to play the game in asking this sort of question. Instead, for the programming beginners like Becca, it was a period of confusion and a reminder of just how far behind they were.

This lecture discourse pattern also meant less class time for the planned basic content, an effect that may have increased inequity for beginning students who would be less likely to know the content already or grasp it easily on their own. Advanced questions also seemed to preempt other more basic questions, since questions about what a basic concept means would seem embarrassingly behind in a discourse focused on topics even more advanced than the class.

Yet again, we note this is not a simple criticism of instruction. Phil is employing a responsive pedagogy, his class is fun and engaging, some students are genuinely curious and it is not clear at all that shutting down student curiosity is something to advocate for. On the other hand, it raises the question, given the constraints of a classroom, who should we be responsive to, especially in the case that students have different needs out of lecture? Can we be responsive to a student who is not speaking? Can we (students, teachers) empathize with other students' perspectives enough to notice when a student is being left out or made to feel bad? Are we, in the culture of engineering education, so accustomed to these ways of participating in a classroom that we are unable to notice them?

Individual Labwork Constructing and Coopting Engineering Status

Ability hierarchies were strengthened in lab, where in a novel pedagogical approach students learned to program by working on authentic engineering tasks. In general, lab was a much more public space than a dorm room or lounge where a student might typically complete programming assignments. Students are packed in close to each other while working, either individually or in pairs. Particularly on individual lab days, everyone can see who is walking up to get the materials for the next step in the lab, who has finished early and left already. Familiar patterns of which students finished first could be observed, patterns which provided another visual reminder of students' prior programming background and status in the class. Likewise, if the room is quiet, the mere sounds of other students cursing their equipment or celebrating successes inevitably send messages of where others are on their assignments. Alongside the unique affordances of the space for collaboration and authenticity, in this setting everyone ends up knowing how everyone else is doing: the public display of ability.

For several labs, another woman in the class, Diana, sits next to Becca and tends to guide her through the work. They enjoyed working together, and like many of the students they tended to talk as they completed their individual labs, collaborating and sharing ideas within the bounds of what the class counted as doing individual work. Diana usually moved somewhat quicker through the lab, having had some programming experience with Arduino before. So Becca often asked Diana what her next step should be, or Diana would look at Becca's circuit to try to help see where it went wrong. Thus the direction of knowledge flow and implicit expert positioning among students also went in predictable patterns related to programming background and status. This pattern had unfortunate byproducts, Becca said she often felt like a nuisance and constantly in need of help from others who were trying to complete their own individual labs. Additionally, the information being shared was often practical and solution-oriented (e.g., Diana suggests a needed command, Becca asks what's wrong with her circuit) rather than how or why to approach a problem in a certain way. This pattern was common throughout lab, appeared to be a natural and agreeable way to work for both Becca and Diana, and in some ways makes sense-- an engineering class may typically be more solution-oriented than theoretical. On the other hand, it may prevent the students receiving quick fix solutions from accessing more powerful content knowledge about strategies and underlying phenomenon. And since those with no programming background are much more often the recipients, this knowledge flow could be seen as a missed opportunity for ameliorating those gaps. Becca would have less opportunity to learn how to approach these problems better herself in the future.

In this setting, particularly dramatic or surprising successes would garner the attention of much of the lab, perhaps winning applause or cheers from across the room. Diana won one such moment of praise when she helped troubleshoot a problem in the example code which all other students and even the TA was stuck on. Becca nearly had a similar moment. A few minutes before Diana's final breakthrough, Becca was considering the fact that they appeared to have been given fundamentally broken example code. She realized that there is a lab section before theirs, so if the example code were really irreparably broken, they would probably have received a warning about that from the prior lab TAs. She announced this, quietly, and to Diana. When Diana asked her what she had said, Becca repeated it even more quietly, as if embarrassed to make her thoughts public in the lab space which was particularly quiet at that moment. A more advanced student across the room, Sam, must have heard the comment-- he immediately asked the same question of George, the TA. George responded, "good question." Instead of Becca, it is Sam who is constructed as a good question asker in this moment. This was not some innate lack of confidence or a shy feminine speaking style causing her to be overlooked, those descriptions did not fit Becca in other settings. We see Becca's situational quietness in this moment as a natural response to being in a public competition where she feels she lacks the resources (programming background) to really compete. Just as it is Becca's quietness which prevents her recognition, it is Sam's loud confidence and social standing which let him feel free to share his (or others') intellectual thoughts with the TA without second-guessing himself.

On ordinary days, one's status in lab just came down to how quickly you finished a step, or finished the entire lab, how often you came up with uniquely correct insights. Becca was never well-positioned to win that game. But it was not inevitable that lab became a daily experience of failure. Though taken for granted in a culture that so consistently produces a slowest or worst programmer, it takes quite a bit of work from many people in order for the lack of ability to be measured and appraised.

Status and Inequity in Group Labs

Group labs took some of the pressure off of students like Becca. The fact that on these days student pairs were supposed to work together on each assignment meant not worrying about being behind and lost all alone. But producing one joint implementation also meant lab pairs had to share or divide intellectual and physical tasks. Students with less programming experience typically did less of the physical programming and circuit-building within their teams. They also did not usually set the overall strategy for the team at the beginning of the assignment or at key decision points. Programming is a process of putting forth ideas and debugging them, finding out why they didn't work. Thus the fact that beginning students ideas' were not put forward decreased the potential that they could learn from their mistakes and improve as coders. While there is potential for the reverse to be true (learning by observing an expert at work), in programming, where so much of the approach can be idiosyncratic, unexplained, or even simply on a computer over which you are not given control to read and follow along at your own pace, the effect is often that the student who is less involved in doing the work receives much less educational benefit.

In addition to the potential inequities in learning, there was a status hierarchy communicated in group lab pairings. When Becca (and other beginning students) was paired with a student who was much more expert, she was frequently "mini-lectured" by the more expert student in the pair. This was a welcome change for Becca, who much preferred being taught to feeling lost or ignored. When paired with another beginning student, the Becca's role on the team increased; but they were slower and more stressed by competing with the other teams completing their work. In one case, Becca is doing very little, in the other she is worried and stressed.

One could look at this scenario and claim Becca is lazy or not trying, she prefers teams on which she is expected to contribute little to settings that challenge her. Or one could blame the advanced students for dominating the computer and never letting the novices work. But instead consider how all of this appears perfectly natural-- in an engineering setting where the final product is valued and no guidance has been given for what counts as learning or participation in a group, of course we would have the stronger and more experienced programmer do most of the work. And of course two novice programmers are slower and more stressed, when they are inevitably compared to the two expert programmers at the next desk. The naturalness of these actions within this setting belies an underlying competitive and meritocratic culture which measures results over learning.

Instructors, students, and Becca herself developed more or less shared impressions of her weak ability, of her essentially being not cut out for engineering. Becca switched majors and avoided other engineering-related fields because she did not want to encounter more programming classes. Was something different about Becca versus her other classmates? Surely. But that is only the smallest piece of what constructed her educational problem. The point of the stage 3 analysis is that *It takes many actors working within the classroom interaction, constrained by institutional and disciplinary forces, and given meaning by a culture in which it exists, for Becca's lack of ability as an engineer to be constructed. Let's restructure the world so that the persistent problem of students "not cut out for engineering" stops coming up.*

Epilogue on the student trajectory

We, as researchers, do not want to overstate the power of this research to pinpoint why precisely one individual's life takes the path it takes. Nevertheless we, as authors, recognize that readers often want to hear a story's ending, how things worked out for people in the end.

In the end, Becca ends up abandoning her dream of being an electrical engineer. She is more or less forced to, by institutional gatekeepers and grades earned in Physics and Chemistry in particular. If she had had more positive experiences in engineering, and if her family could afford for her to try again, perhaps she could have tried another engineering major at State University or transferred to a different university to be an electrical engineer. She considered these options. She thought about trying again with mechanical engineering, perhaps a better fit for her, but she realized it also required programming (Matlab), and after her experience in this class she wanted a major that wouldn't require any more of it, even though she received an A or A- in the class. In our follow up interview, she brushed those grades off as the professor being generous with her for having tried hard, the fact that the final was open book and she had brought copious notes. They didn't signal any innate ability in programming or engineering. She decided on a math major, which she saw as rigorous and valued in society but which, importantly, required no more programming. (And also, less gatekeeping—one can register as a math major at State University immediately, rather than playing a waiting game in the institutional limbo of L&S.)

So officially, Physics and Chemistry and institutional requirements were what pushed Becca out of engineering, not the programming class. But, effectively, the day-to-day emotional strain of being found an incapable engineer (in this and other classes) were the primary pressure cooker that built a constructed classroom ability into an institutional trajectory, and turned the day-to-day experiences of marginalization and degradation into a destiny. The fibers became a rope.

Discussion

Equity landmines hiding in the mundane

Using the theoretical lens of "turning away" from a particular struggling student who is deemed "not cut out for" engineering, we have turned our attention to the ways that many other actors (students, teachers, societal labels, engineering culture) contribute to and construct this student ability in everyday moments. Is there something different from her peers about Becca's background, and even perhaps, her strengths as a programmer and engineer? Certainly. But those represent only the smallest piece of the work that constructs her ability. Why should prior programming background be such a salient dimension in an *introduction* to programming course? The answer is it potentially need not and should not be, but contributions from many actors inside and outside of the instructional setting (often unwittingly) make it so.

In a time-honored ethnographic tradition, this work attempts to "make the familiar strange," and calls into question seemingly mundane pieces of cultural work—the language of the PowerPoint slides, the seating position in a classroom, the moments of recognition in lab—as constructing ability and inequity. We could include many more examples in our list depending on where we cast our gaze: the tests, grades, GPAs, student questions, student answers, tones of voice, course sequences, majors, honors, school pedigrees, and disciplinary pedigrees on which educational life in America runs. These pieces of "normal" hierarchical meritocracy are a major part of the systems which create educational problems of failure, the "water" of that educational problem.

Grappling with the culture

If our research reflects an authentic picture of the culture which created the educational problem, we, as a discipline and society, will need to ask and answer real and fundamental questions about the work we do. Perhaps some will see a legitimate reason to being meritocratic, exclusive, and elitist—if everyone were an engineer then no one would be, and engineers occupy a particular position in a society grounded by meritocracy and capitalism. Perhaps it would not be shocking to learn that higher education is functioning primarily to reify an elite based on prior skills and performance rather than to foster learning and growth for all. Perhaps engineering educators feel they rightly focus on products and performance over evidence of learning.

But education is also bound up with goals of democracy and opportunity, and we pride ourselves on being spaces of learning and growth where hard work will pay off. Education need not be in the business of constructing educational problems, creating failure and reifying preordained success. To be in the business of sorting students is an unambitious goal for an educational system, and it inflicts a great toll on the many Beccas caught up in the process of being deemed "not cut out for" it. But disrupting "normal" systems of inequity and living without hierarchies of meritocracy in education would require a radical restructuring of life in America.

We, the authors, suggest grappling with the tension between our lofty goals and the reality of our education system, between accepting and seeing the world as we know it now, and envisioning and enacting radical possibilities for change. We suspect that only by appreciating the full weight of the intractability of this way of life, will we develop the will and the tools to change it.

What can be done?

We, like McDermott often did[1], want to largely resist the urge to make specific suggestions for intervention. If we are right about the pervasiveness of the cultural construction we have identified, it will take from each of us more reckoning with the problem and more ingenuity to find ways to change the system.

Nevertheless, two specific recommendations come to mind, one for practitioners and one for researchers. As noted, among teachers the stage 2 tendency (to look for differences in a student's background as an explanation for their struggles) is pervasive and tempting. But once we zoom in on only the individual struggling student and their background, there is almost never any material left with which to reasonably address the problem. Instead, perhaps the theoretical approach to "turning away" could become a pedagogical intuition. [Of course, we have never been advocating literally turning away from struggling students in the sense of withholding encouragement and individualized help.] When concerned about a "struggling student," perhaps the instructor could develop a habit of reflecting back on what has gone into constructing the student as struggling. Perhaps, instructors would ask: Are my instructional practices fair to this student? How could things be different so that this student isn't a student that "needs help"? Am I making my slides understandable by this student? Are students creating a hierarchy amongst themselves in ways that I could interrupt?

Likewise for researchers involved with diagnosing and addressing educational problems in undergraduate engineering, we once again put forward the unusual analytical approach of the cultural construction paradigm, and in this case look at what has been gained by "turning away." Many of the research findings reported above grew out of eliciting the first-person perspective of the marginalized student via one-on-one interviews, a familiar starting point in qualitative research addressing identity and equity issues. However, guided by the orientation to "turn away" from the individual, the analysis substantially moved past the individual interview to look at *in situ* interactions and systemic forces, using the interviews to help cast our analytical gaze on what elements of the educational system were at play in the construction of the student's ability. We believe the orientation to look outward from the individual, with an ethnographic approach that pools interviews, classroom interactions, institutional labels, systemic forces, and culture, has led to a more robust and powerful analysis of the educational problem. Relying only on interviews may be asking students to do all of the work of noticing the “water,” when that which is mundane and pervasive may be just as difficult to notice for students as for educators.

In conclusion, we return to McDermott’s reframing of culture, not as “the past cause” to a given student’s educational status. If we are to truly grapple with the nature of our educational problems, we must acknowledge that culture, our culture, is “the current challenge” to any future we hope to create.

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