AC 2007-1234: SHOULD I STAY OR SHOULD I GO? ENGINEERING STUDENTS' PERSISTENCE IS BASED ON LITTLE EXPERIENCE OR DATA

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Should I Stay or Should I Go?: Undergraduates' Prior Exposure to Engineering and Their Intentions to Major

Abstract
This research contributes to the body of literature relating to how environmental effects of classroom instruction, departmental culture, and institutional structure influence students' decisions to major in engineering. Engineering students at two different higher education institutions were interviewed (n=32) and surveyed (n=76) during their freshman and sophomore years. Interview questions and survey items probed students' exposure to engineering prior to college and the strength of their intentions to major in engineering. Findings reveal that most students have very limited exposure to and knowledge of engineering before they begin college. In addition (and possibly as a result), students' intentions to major in engineering waiver, even while they actively complete engineering requirements. Nearly all students in our sample were entrepreneurial in seeking experiences within and outside of engineering to help them decide on their major. Implications of this research are that 1) attrition rates from engineering may be inflated, and 2) classroom, departmental, and institutional adjustments could increase retention of students in engineering.

Persistence in Engineering Education
From the era of Sputnik through to the present, concerns about preparing sufficient numbers of engineers to meet the demands of industry and national security have gained national attention.[1,2,3] Specifically, researchers have sought to understand the attrition from fields requiring preparation in science, technology, engineering and math (STEM). From 1975 through 1999, attrition from STEM programs has continued, to the point where the U.S. has slipped from third to fourteenth place among twenty countries worldwide in the proportion of twenty-four-year olds who hold STEM degrees.[2]

Researchers over the past thirty years have studied several factors related to enrollment and attrition of students in engineering programs. These factors can be grouped as *past*, *present*, and *future* variables. Past factors include high school grade point average (GPA), SAT scores, parent income, race, gender and ethnicity, high school math attainment, to name a few. Present variables include college GPA, factors related to school environment, and student effort and beliefs. Future variables include students' beliefs about salary and work demands, career attainment, and expectations related to marriage and family.[3]

While student demographics and social history influence college choice, current research is increasingly examining the effects of the college experience itself on students' decisions relating to their major and career. In particular, research into engineering persistence is examining the academic environment—classroom instruction, social pressures, departmental culture, and institutional structure—to determine the extent to which these factors impact students generally, and in particular women and minority candidates.[4]

Daempfle found that faculty interaction as well as interactive classroom instruction does have an effect on retention, though student background and gender influence the extent of these effects.[5] Jackson et al. looked at past, present, and future variables of those who persisted and those who did not persist in engineering majors and found first-year GPA to be the strongest predictor of

persistence. Other variables (past, present, and future) that also influence persistence, include SAT scores and self-rating of math ability. Like Daempfle, Jackson et al. also conclude that persistence in engineering involves an interaction of several past, present and future variables.[6] Similar results were found by LeBold and Ward, whose survey data narrowed predictors of persistence to high school math, science, and English grades, high school rank, as well as first-year college cumulative GPA and college-level self-perceptions of math, science, and problem-solving abilities.[7] Moller-Wong and Eide also used survey data to narrow variables predictive of retention in engineering programs, focusing on demographic variables related to high school courses taken, high school grades, SAT scores, and race. The only college-level variable that was significant in their study was marital status.[8]

While regression and correlation methods have yielded some consistent findings, they do not explain attrition. The distinction between past, present, and future variables is artificial, since variables are not independent. As an obvious example, high school coursework and grades (past variables) are of course going to influence freshman course taking choices and GPA (considered present variables).

More recently, qualitative studies have tried to identify in holistic and naturalistic ways how students' experiences before, during, and after college influence their academic and career decisions. Qualitative data can be a potent means by which to understand the motivations that result in decisions to persist or not. Leydens et al. note that the "broad purpose of qualitative research is to understand more about human perspectives and provide a detailed description of a given event or phenomenon" (p. 65).[9]

Increasingly, qualitative inquiry is being used to further our understanding of students' decisions about their majors and careers. Seymour and Hewitt's extensive, three-year study relied on observation and interviews of 335 students in seven institutions in order to gain valuable insights into experiences that strongly influenced students' decisions whether to persist in engineering.[10] In their study, persisters and non-persisters were not distinguishable by high school GPA or other commonly cited demographic factors. Rather, the authors conclude that "the most common reasons for switching arise in response to a set of problems experienced by switchers and non-switchers alike" (pp. 392). In their study, issues relating to classroom instruction, departmental culture and institutional structure were pivotal in students' decision-making.

Besterfield-Sacre et al. recognized the role of students' attitudes during decision-making about their major. These authors concluded that institutional structures (including high credit requirements in engineering), prematurely force students to narrow their career interests.[11] Other work in student learning has identified the importance of student attitude in decision-making. Bransford et al. have documented how students' emotional reaction to a learning situation complicates their ability to gain mastery over the new knowledge. Students who feel frustrated or defeated by their learning experiences do not gain mastery over new material. These findings are directly relevant to a study of engineering persistence, because both freshman GPA and self-perception of math and science ability have been consistently linked to attrition.[12]

In spite of the extensive study into attrition of undergraduates from engineering programs, our understanding of student decision-making about the engineering major is still nascent and

evolving. Quantitative and qualitative inquiry over the past twenty years have outlined the complexities involved in students' decision-making, but have provided no definitive insights. Ethnographic studies published in the last ten years have pushed our understanding forward, but, (by the nature of the methodology), these studies involve limited numbers of participants. Such work is cumulative. At this stage, inquiry that gets eye-to-eye with students is the most promising means of furthering our understanding of students' attitudes and behaviors that result in the important decisions they make about their majors and careers. The current study followed a single cohort of students from two higher education institutions from their freshman through senior years. Using both quantitative and qualitative data, we scrutinized students' first two years in college—to the point at which students declare their major. In this paper, we analyze how students' perspectives and experiences shape their decisions whether to persist in engineering.

Research Methods and Participants

The Center for the Advancement of Engineering Education (CAEE) is a multi-year study of undergraduate engineering education. One facet of this research is the Academic Pathways Study (APS), which follows a cohort of students enrolled in four different universities nationwide from the freshmen through senior years.[13] Identified by pseudonym, these institutions are Mountain Technical Institute (MT or Mountain Tech), a small public university specializing in teaching engineering and technology; Oliver University, a private, historically black mid-Atlantic institution; University of West State, a large public university in the Northwest; and University of Coleman, a medium-sized, private, comprehensive university on the West Coast. Participants were chosen based on their intention to major in engineering, as indicated by their application and university enrollment documents. Students were asked to participate in the study via email and/or during orientation activities. Students were selected from those who expressed an interest in participating in the study, although women and traditionally underrepresented minorities were intentionally over-sampled.

This research was conducted at two pseudonymous APS sites, Coleman University and Mountain Technical Institute (MT or Mountain Tech). Coleman University is a private, comprehensive institution, offering undergraduate majors in the humanities, engineering, math and sciences, and social sciences. MT is a state-funded, technical institution that offers undergraduate degrees in engineering, chemistry, mathematics and computer science, and economics and business.[1] The difference between these two institutions in terms of institutional focus and academic offerings available is significant; Coleman offers a broad range of alternatives to majoring in engineering while the MT does not.

The two institutions also vary in terms of student demographics. Although both Coleman and MT engineering programs enroll similar numbers of women and Latinos/as (approximately twenty-four percent and eight percent, respectively), Coleman's engineering students are fifty percent non-white while MT's are approximately fifteen percent non-white. Foreign nationals comprise ten percent of Coleman's engineering students and four percent of MT's engineering students. Both institutions are highly selective, with many students having completed at least one and often several Advanced Placement (AP) courses before entering college.[14]

[1] All institution names and student names are pseudonyms.

Data for this paper include semi-structured interviews and informal conversations from a targeted sample of students (n=32), complemented by survey data from a larger cohort of students (n=76). The qualitative data collected from the targeted sample is the focus of this work; survey data is included in this paper only as it further informs interview data. Students were asked questions about their high school experiences, how their interest in engineering evolved, their collegiate experiences, and their post-baccalaureate intentions.[15]
Data were collected by digitally recording interviews ranging from one and one-half to three hours in March through June of 2004 and 2005, when the participants were first- and second-year students. Because of attrition and replacement, at MT, the total number of interview participants for years one and two is 17; the total number of transcripts is 32. At Coleman, the same 15 participants were interviewed both years; there are 30 transcripts.

Audio files were transcribed into text, and the Microsoft Word files were formatted for coding in ATLAS.ti 5.0, a software program frequently used in qualitative research. Concurrently, researchers at MT and Coleman worked on developing a coding scheme to use in analysis of transcripts; then, with collaboration of researchers at Oliver University, the codes were compared, refined, and merged into one analytical tool. Development of codes was a time-consuming process; transcripts range in length from about thirty pages to about 100 pages and require from four to eight hours each to read and code.

The coding scheme has 18 major level and 64 sub-field codes. The main category describes a feature of the participants' speech that aligns with an APS research question, in particular, education and identity; the sub-categories identify finer levels of detail within the main category. A notes and guidelines section provides clarity for researchers, particularly for instances of overlap between main-category entries. A segment of speech can be multiply coded. Several APS researchers trial-coded sample segments of transcripts and then refined both codes and data-interpretation practices to develop reliability between coders. Then, the transcripts were coded in ATLAS.ti. Coders do not need perfect agreement on codes, and we have not developed reliability scales due to the qualitative nature of this research methodology; informative analysis emerges from discussion of differing perspectives.

Using ATLAS.ti, researchers can generate reports on specific codes, isolating, for example, discussion of identity from one particular participant, each female participant, all participants who are mechanical engineering students, and/or all interviews conducted in a particular year. ATLAS.ti can also search for a recurrent word or phrase. With a set of codes isolated from the larger transcript, researchers read, make comparisons, and begin to follow emerging themes. The quotes we have included were culled from interview transcripts. Some quotes have been lightly edited in order to remove distracting non-content features, such as "like," "you know," "um/uh," etc.

The large cohort of students (N=76), including the targeted sample, completed surveys twice yearly. The first survey was administered during either the fall or winter academic term, followed by a second survey administered during the spring term. Surveys were delivered online with a 100 percent response rate. Reliability on aggregated variables was alpha = .70 or higher. Surveys probed students' persistence in the engineering major and many aspects of their

collegiate experience.[16] The survey results provide quantitative data that complement and validate the rich qualitative data from targeted student sample.

This paper discusses findings from students' freshmen and sophomore years—that portion of their undergraduate experience during which most students confirm their decision regarding their majors.

Choosing Engineering: Students' Exposure to Engineering Professions Before College

One important element not heretofore studied in engineering education is students' understanding of the engineering profession and how that influences their major and career decisions. Pascarella and Terenzini summarize literature relating to "career maturity," noting that one-third to two-thirds of undergraduates switch majors before they graduate (p. 425).[3] Most students at each institution had little exposure to engineering before entering college. The students were prompted to discuss how they became interested in engineering as well as the range of academic majors they were considering during both their first- and second-year interviews. We coded the students' interviews for their narratives addressing the variety of exposures they related to their interest in pursing their academic majors. We then evaluated each student's exposure to engineering upon entry to college as either *low*, *moderate*, or *high* and developed a rubric by which we could compare exposure. Criteria for these ratings are discussed below.

Low Exposure: Students may or may not know a family member or friend who is an engineer, but other than that, the student had no direct, engineering experiences. These students, like most students in our sample, might have done well in high school math and science courses and been encouraged by their teachers to pursue engineering. These students might have engaged in engineering-like activities, but they have not been mentored by engineers. For example, a student might have participated in Odyssey of the Mind, a national, project-based competition where students apply math and science to build various projects according to specific criteria. While such an activity is "engineering-like," when it was not specifically mentored by an engineer, we did not consider it engineering exposure. Similarly if a student had extensive experience programming or building computers but was self-taught, without the benefit of having received any formal, discipline-based computer science, we considered this *low* engineering exposure.

Grace entered Coleman with low exposure to engineering. She enjoyed her math and physics classes in high school, and during her senior year, she had an opportunity to go on a field trip to a local university. The field trip included tours of a few electrical engineering labs and observing an engineering design competition. Grace admitted that before entering her senior year in high school, she had not really considered majoring in engineering. In fact, she could not recall meeting an engineer prior to her field trip to the university. After she was admitted to Coleman, Grace participated in a summer program for students interested in engineering and science.

Although he excelled in math and science in high school, Mark had had low exposure to engineering prior to attending MT and actually expressed strong interest in meteorology because of a childhood experience with a hurricane. He applied to MT because of information he

received in the mail as a high school student and because of the institution's good regional reputation. Prior to the fall term of his first year, Mark visited MT and attended sessions describing Geophysics. Mark had already decided to enroll in MT and matriculated because he believed the Geophysics major would allow him to study weather phenomena in pursuit of a meteorology degree.

Moderate Exposure: Students may or may not know a family member or friend who is an engineer. The student has had direct, *mentored* experiences related to engineering activities, such as taking apart circuit boards, building inventions, taking engineering classes, or participating in an engineering program before entering college. If a student had engaged one or two of these activities, we considered their exposure moderate.

Emma had moderate exposure to engineering before entering Coleman. She took a five-week science exploration summer program in high school focusing in engineering. University professors offered hands-on engineering-related activities and lectures. Her grandfather was an engineer, and she described her childhood when the two of them took apart television sets and radios so he could show her how they worked.

At MT, Christina had had moderate exposure to engineering prior to matriculation. Her father is an engineer and shared his enthusiasm for science and engineering with his children, bringing home science kits, taking his children to his workplace, and explaining what things are and how they work. Of the twenty participants enrolled in our sample at MT, Christina is the only one who participated in a summer program to encourage interest in engineering. She had also taken an electronics course in high school and worked closely with her father to complete projects when she did not understand the content.

High Exposure: The criteria here are similar to those for those with moderate exposure; however, students rated as *high exposure* have had deeper and/or broader experiences than those with moderate exposure, usually participating in multiple engineering activities before entering college.

Steve enrolled at Coleman with relatively high exposure to engineering. He had taken two years of CAD courses during his freshman and sophomore years in high school, and amassed a good deal of experience in mechanical drafting, even designing (among other things) a house on a slope and an airplane. Steve's grandfather was a civil engineer, and during high school Steve participated in a three-month internship with a civil engineer employed by the local Department of Transportation.

Joe at MT demonstrates relatively high exposure to engineering prior to his enrollment. His grandfather had been an engineer for an aerospace company and provided the introduction to the participant's field of study: metallurgical engineering. His high school offered Tech Lab, an engineering laboratory course in which he repeatedly enrolled, building Lego cranes to lift and move loads and completing other open-ended problems. But it was a voluntary activity as part of a high school English course that helped to cement his love for engineering. As a sophomore, Joe worked with a friend to build a trebuchet that was twelve-feet high and could catapult a one-gallon bottle of water the length of a football field. He even moved the trebuchet to MT to

continue tinkering with it, and housed it in the garage of his apartment building, while his vehicle sat in the driveway, exposed to the elements. Additionally, as a hobby, Joe began practicing blacksmithing while in high school, an activity he sees as directly related to his major.

It is notable that of the 32 students whom we interviewed, only six (nineteen percent) had high levels of exposure to engineering prior to college (Table 1). In fact, it is probably rare that students considering any major to have had extensive exposure as freshmen. However, other non-engineering majors may allow for more opportunity to explore before students must commit to the degree. The high number of courses and units required for the engineering major forces students to commit to the major early on, beginning the necessary course sequences from their first term.[17] As a result, students must commit to the engineering degree before they have had a chance to learn much about engineering as a discipline or as a career. This can affect their level of commitment and may explain some attrition patterns.

Table 1: Summary of Students' Level of Exposure to Engineering Professions Before College (Coleman n=15 | Mountain Tech n=17).

Exposure	Coleman (n=15)	Mountain Tech (n=17)	Totals (n=32)
Low	10 (67%)	10 (59%)	20 (63%)
Moderate	1 (7%)	5 (28%)	6 (19%)
High	4 (27%)	2 (11%)	6 (19%)

Our data suggest that the course offerings at both Coleman and MT influence the engineering-commitment profile. While several students at Coleman reported that they chose that institution because it offered degree program options other than engineering or a technical field, students at MT have limited degree options beyond engineering. Students can study engineering or one of three options: mathematics and computer science, economics and business, or chemistry or leave the institution if they decide that engineering—or MT's narrow focus—is not for them. Given this difference, it is reasonable to assume that students enter MT more positive about their intention to complete a degree in engineering than do many or most students at Coleman. Yet at Coleman and MT, several students who described themselves as "positive" about majoring in engineering changed their minds. In fact, when all students in our study were surveyed at the end of their junior year, 39 of 76 students (forty-nine percent) at MT and Coleman reported having experiences that prompted them to doubt whether to continue as engineering majors.[2]

The Effects of an Institution and the Course Offerings

Coleman University

Coleman admits students to the University rather than to specific departments or majors. Students at Coleman are not required to declare their undergraduate majors until the beginning of their junior year. Most students declare their majors as sophomores, though they may declare sooner. Since there is no acceptance decision, students' grades or the amount of coursework they have taken are not factors to bar them from admittance to engineering. Furthermore, while there is a suggested but not required pre-engineering curriculum, students have opportunities to explore courses offered in engineering as well as other colleges.

[2] APS data, spring survey analyses, unpublished.

Although all students in the study indicated on application and enrollment materials an intention to major in engineering, many students at Coleman chose a comprehensive university precisely because it offered alternatives to engineering. Below, we cite typical comments to the first-year question, "What made you decide Coleman?"

> "State Tech was too limited. It's just tiny; and I like a lot of things; I don't like just engineering and if I decide I don't like engineering, I'd be stuck." *Paula*

> "Because I wasn't sure that I was going to do engineering, and I guess I still am not. If I had gone to State Tech I'd probably feel like just going straight into engineering because they're so intense over there, and they're just almost all engineers. But here I have the opportunity to look at all these other different interesting things, still do engineering, and take some really cool classes from the humanities, too. So, it seems like I can have my useful engineering major and then pursue the fun stuff on the side." *Dana*

While Coleman does offer opportunities to explore, students have great pressure—both financial and as part of institutional culture—to complete a major within four years. As is typical of other U.S. engineering programs, the credit load for engineering majors is the highest of any other on the Coleman campus.[18] Students must complete 180 quarter-credits for the baccalaureate degree, for engineering students, 90 to 134 of these credits are specified by their majors. In contrast, most humanities and social science majors at Coleman specify an average of 60 units, with a range of 43 to 88 units. The specific number of units depends on the particular major and whether or not the student is pursuing an honor thesis.

To complete engineering-major requirements within four years, students must carefully plan their lower division engineering-science related coursework in order to be "on track" for a four-year graduation. Students must balance this pre-engineering coursework with the humanities and writing coursework which Coleman requires all students to complete during their first two years of study. Therefore, although students have opportunities to explore fields other than engineering or even different engineering fields, practical constraints force them to choose wisely. Exploring alternative academic interests through coursework sometimes "puts students behind" the four-year schedule or forces them to take a course overload. Students can explore, but, to retain the option to major in engineering, they must maintain steady progress towards completing engineering-related coursework.

MT

MT students also are admitted to the institution, rather than to the degree program. Students have the option to remain undeclared for their first three semesters. By the second term of the sophomore year, students begin taking courses in their major departments, and the strong cultural and practical expectations are that a student will have chosen a major by the mid-point of the second year of study.

Almost universally, students at MT report that they have chosen to enroll at an engineering institution because they are "good at math and science." Frequently family members, mentors, and high school teachers and/or counselors have told the student that engineering would be a

good pursuit for someone with those abilities. Other students choose MT because of its strong regional reputation for providing a high-quality education in engineering.

For those at MT considering alternatives to engineering, the nature of student explorations differ from Coleman, in part because the options of students at MT are limited by the engineering and technical focus of the institution. First- and second-year course offerings are tightly sequenced and packed with pre-engineering requirements. Junior- and senior-year courses are governed by departmental diagrams of required courses and their pre-requisites. Students need up to 146.5 credits to graduate—eighteen engineering credits every semester—and, because of MT's small size, some departments only offer courses once a year; if a student falls out of sequence for any reason, s/he must wait an entire year to make up lost credits.

At MT, as at Coleman, fundamental courses were often seen by students as something to get through before they could begin to engage in their "real work" as engineering students. The two required semesters of physics, an ethics and technical writing class, and an earth science class were widely described as something to be survived before students could get to the Holy Grail: courses in their majors. Nevertheless, as with Coleman, required courses also introduced students to non-engineering majors and faculty. This was particularly the case among students who had been considering a major in Chemical Engineering. Many of the seventeen students we interviewed expressed a definite disinterest in pursuing Chemical Engineering, based on their experiences in college chemistry. Interestingly, this choice is not reflective of the quality of teaching; a number of students who made this assertion praised their chemistry professor and claimed that it was their own inability to visualize the material that made it an unattractive course for them.

MT has recently introduced a biological engineering minor and a humanitarian engineering minor. A third, long-standing minor option is in public policy, although students must apply to the program in the fall semester of their first year to be accepted; many students who might gravitate toward the program miss the opportunity even before they recognize they might be interested.

Students who have developed strong social networks, accumulated a number of credits that are not readily transferable to non-engineering colleges (e.g. thermodynamics and statics), or those who rely on institution-specific scholarships struggle with what they should do. Some stay at MT to completion of their degrees, even though their commitment to and satisfaction with engineering is low.

The most striking example of this struggle at MT is with Anna, a student with low exposure to engineering. She began in her first year as an engineering physics major, an ABET-accredited degree at MT, but maintained many of her interests from high school, including biology, psychology, and art. The curriculum at MT was a struggle for her, especially when she began to realize that engineering might not be a good fit. In this lengthy excerpt from her sophomore-year interview, Anna describes her exploration through nearly every major at MT in her effort to stay at the institution through her undergraduate degree.

> "It [the Physics major] wasn't working; it wasn't giving me the tools that I thought it [would]…. Well, see, the thing is too, I really didn't get into a lot of the major physics program classes yet, but I have friends who are in the Thermal Physics class and they'd ask me on their homework a couple times, 'What do you think about this?' And, I'll look at it and stuff and it's just like pages of derivation in math and algebra and… it's just that I don't care….It wasn't working for me; it was too much math and theory…. There are kids who are just [snaps fingers]; they get it. I'm more like, with the biology thing, I can read it, and I can look at the material, and then I'll remember it, I'll soak it up like a sponge… And I don't want to spend my life trying to figure out how to do something and then never get to do it because it took me so long to learn it. You know what I mean?"

When asked what other majors she had considered, Anna described in detail her process for deciding what to choose.

> "I x'ed out chemistry long ago [laughs], chemical engineering, yeah. Um, petroleum engineering, no. Petroleum engineering doesn't interest me at all; like I hated thermodynamics and petroleum engineering and chemical engineering; if I was in thermo-type classes that'd kill me."

When asked to clarify if processes—such as those critical to chemical engineering—were simply not attractive, Anna responded,

> "It's not as interesting to me….And then mechanical engineering just seemed too, too dry. Same thing with civil, too dry….Well, like biology and the application to that; that makes it very, very exciting for me. The biomaterials program, they have graduate programs in the MME [Materials and Metallurgical Engineering] college that deal a lot with the biomaterials or making false teeth or making bone or making a substitute for bone….My circuits class: working with the circuit board just didn't do it for me….I like to create something and then see if it blows up or not but, it doesn't give me any thrill at all….So electrical engineering, that's out. And then, um, let's see what other kinds of engineering did I X out?" *((I: "Well, mining is here."))*

> "Mining, yeah; I'm not a miner. I liked rocks, too, I mean geology…. I don't like maps very much. They don't make sense to me [laughs]….So I was just kinda like, it was either MME or I had to go: 'Bye, bye Mines.' But I don't want to leave…. And, you know, worst case scenario—I don't like this either—but it's still gonna give me some hard core science that maybe I can figure out, something with. If anything it'll give credibility, too, you know what I mean? You hate to think of it that way but it, it's true. If you have an engineering degree and you're an artist, then, you have something to fall back on."

Intention to Major: Does Engineering Work for Me?

Based on our analysis of two major category codes, "Academic Major Influences" and "Academic Navigation," it became clear that students at both MT and Coleman wrestle actively with their decision to major in engineering. (MT's students, as we have just discussed in Anna's case, also struggle with whether or not an engineering-specific institution is a good fit for their

interests. For this paper, we do not discuss in detail migration of students from the institution.) Despite the constraints at each institution, we discovered that students are anything but highly intent on entering and completing a specific engineering degree. We learned that students vary in their commitment to a certain degree path as well as to engineering as a field of study.

The 15 students[3] at Coleman and 16 students[4] at MT we interviewed at the end of their first year fell into three groups, in terms of their intention to declare a major in engineering, *unsure, mostly sure*, and *positive*.

Unsure Intention: First are those who were *unsure* about whether to pursue an engineering major. These students were more likely to explore areas outside of engineering than deepen their exposure within engineering. While continuing to take courses that kept them apace of the engineering requirements, each of these students actively explored courses related to majors in the physical sciences, social sciences and the humanities. Below are excerpts from students rated as *unsure* about their intention to major in engineering.

Emma, at Coleman, describes the perfect, eclectic (non-engineering) major for her during her first-year interview:

> "I don't know. A combination of engineering, econ, and comparative, like race studies, I think. Something like that ((laughs)). That's if I could make up my own and be able to do it in four years or however long I needed to have to do it."

At MT, Jane describes her lack of knowledge about the field and ambivalence toward the professionals she has had prior contact with.

> "Honestly, no, I had no idea what engineering was, I was just like, 'Okay, math and science school; we got it,' and then like somehow that just kind of became synonymous with engineer-, with that definition. They're like, 'Oh you can be an engineer,' I'm like, 'Okay, I guess so?' And I only really got a feel for what I'd be doing [after I got] up here….I don't know what it [engineering] is. I've always had an odd impression of electrical engineers, really. [A computer hardware corporation] was in [Jane's hometown] and so they're everywhere. They're crawling up and down the walls, and all my friends' dads are incredibly quirky and odd and antisocial and electrical engineers, and that's an unfair impression but that one's [electrical engineering as a major] been eliminated accordingly.

Lisa, at Coleman, describes her interest in engineering, and her wavering intention.

> "For AP and for my high school, I did science major, so that's why I did mostly science classes, 'cause I was interested in science and high school science is a lot easier. So, who knew? And so the teacher was telling us, 'I like engineering 'cause it's a challenging

[3] One of the sixteen students originally in the study had substantial challenges negotiating university requirements and policies. This students' data appeared to be substantially anomalous and were eliminated from these analyses.
[4] One student was added to the MT cohort at the beginning of the second year to replace a student who left MT. This student was not interviewed during year 1.

> major and then also, a lot of money.' And so I just decided that, I did a little research about it; then I decided to come and pursue chemical engineering."

However, when asked if she has already committed to chemical engineering as a degree program, Lisa responds negatively.

> "That was the first two quarters. And now this one…I'm trying to really decide whether it's for me. I don't think engineering was ever something I was interested in doing? I just did it. …But I think my real interest since I was little was always [in] writing. So, I think I just did engineering for the wrong reasons, and so now I'm trying to figure out if that's what I really want to do or if that's really my calling or not."

Roger at MT is uncertain of his commitment to the engineering field and even had been interested in majoring in business in a prestigious, private, mid-western university prior to coming to MT. Although his father is an electrical engineer and although Roger had had moderate exposure through extracurricular activities in high school, he really is not certain what engineers do on a daily basis—or if he wants to find out.

> "I see my dad, he's an engineer. He sits in his cubicle, at his computer all day, typing up code and doing stuff. I don't really want to be doing that but that's engineering for you. I haven't really thought about 'Well, after school, what am I gonna be doing?' I think it's sit in a cubicle all day and I might be doing this, might be doing that, and I really don't know."

Mostly Sure Intention: Second, are those we rated as *mostly sure* they would choose engineering. These students were pretty sure they would major in engineering but felt they lacked exposure to the profession or coursework. These students tended to seek engineering related experiences in order to confirm their intention. Below are examples of students we rated as *mostly sure* they would major in engineering.

In her first-year interview at Coleman, Grace describes her hesitation to commit to engineering as her major.

> "Should I really be in the field that I'm in? My advisor was like, 'Well you seem like you're almost ready to declare,' and I was like 'Um ((laughingly)) no, not quite,' because I haven't actually taken an ME [mechanical engineering] class. So in the fall is when I'll be taking ME 101 and so I'll see, like if I really truly like it. But the [engineering introductory seminar] is, is awesome. I never had to do like really hard work, you know? It was more having fun. … This quarter I'm taking E 14 in the engineering [college], so it's-, I'm kind of struggling with that class a little bit. It's pretty tough and I think that has something to do with me like really trying to figure out if I really want to be an ME. I'll see how it goes next quarter."

A student at MT specifically identifies her absence of a definitive choice in her major—and in her peers.

> "I think we're all for the most part pretty serious about school, and we're pretty sure we want to be engineers." Christina

Positive Intention: Third, are those whom we rated as *positive* that they wanted to complete the engineering degree; these participants expressed minimal or no reservations regarding majoring in engineering, although they might not have known which area of engineering they would choose .

Nate enrolled as a freshman at Coleman nearly certain of his intention to major in engineering. When asked to clarify when he had become intent on engineering, he couldn't remember exactly his decision point:

> "Mmm, I can't even say, don't even-, I don't even know….I was pretty certain it happened some time in high school maybe. Yeah I think it was some time in high school."

As at Coleman, there were students at MT who were steadfast in their intention to major in engineering. Joe decided on engineering and his future college long before his matriculation at MT.

> "I guess, about halfway through high school, I really decided that engineering was the thing for me. I took a couple of courses that were sort of Intro to Engineering, we had this thing called Tech Lab that I took, and I decided that it was the field and then, I sort of started lookin' around at different places. I was talking to one of my teachers who actually works, or interns at a regional national laboratory, and he said they had a lot of good people come out of MT."

Rudy, also at Coleman, was certain of his intention to major in engineering, which made him, in his opinion, unusual for his peer group.

> "I'm rather odd in that I already am pretty sure what I want to do, cause everyone else seems to not be so sure….I think it's very standard to wait until like the end of your sophomore before you declare, [but] I'm almost 99 percent sure that I want to do it, so I figure I might as well just do it [declare the major] now."

Hilary at MT also had long been intending to major in engineering.

> "[In] high school the classes that I actually wanted to go to were chemistry and physics and math and stuff so it was pretty natural that I'd either want to do science or engineering. And I decided engineering because it's more applicable, I think; it has more benefits to humanity than just straight science or more immediate benefits."

An overall summary of intention to major in engineering appears in Table 2; this table includes data from all thirty-three participants from MT and Coleman. It is interesting to note that over half of the Coleman students are positive about committing to engineering, whereas students are more evenly split between positive and unsure at MT. This is surprising in that one might expect

more of the students enrolling at MT (a more engineering focused institution than Coleman) to be positive about majoring in engineering than their peers at Coleman. Our small sample does not bear this out.

Table 2: Summary of Students' Level of Intention to Commit to an Engineering Major (Coleman n=15 | Mountain Tech n=17).

Intention	Coleman (n=15)	Mountain Tech (n=17)	Totals (n=32)
Unsure	3 (20%)	8 (47%)	11 (34%)
Mostly Sure	4 (27%)	2 (12%)	6 (19%)
Positive	8 (53%)	7 (41%)	15 (47%)

Comparing Exposure, Intention and Decisions about the Major

To summarize, students at Coleman and MT generally had low exposure to the engineering profession and varying strength of intention regarding whether to persist in the undergraduate engineering major (Tables 1, 2). Even at the engineering and science intensive institution—MT—fifty-nine percent of those we interviewed had low exposure to engineering before college. Forty-seven percent of MT students and twenty percent of Coleman students were unsure about majoring in engineering in the spring of their first year. Students at both institutions clearly continued to explore their options prior to committing to a major. Nearly all students, even those who demonstrated positive intention, explored courses, programs, internships, and extra-curricular activities either within or outside of engineering as part of a deliberate process to confirm their decisions about whether to major in engineering and, if so, in which area.

Table 3: Summary of Coleman students' Majors Mapped Against Their Level of Exposure to Engineering Before College and Intention to Major in Engineering (n=15).

	Engineering (n=10)	Physical & Natural Sciences (n=2)	Humanities & Social Sciences (n=2)	Undeclared (n=1)
Exposure				
Low	7	1	2	0
Moderate	1	1	0	0
High	2	0	0	1*
Intention				
Unsure	1	0	2	0
Mostly Sure	3	1	0	0
Positive	6	1	0	1*

(*Student who left Coleman at the end of year 2 to pursue work opportunities.)

As it turns out, four of the fifteen (twenty-seven percent) Coleman students eventually chose majors other than engineering (Table 3). One of those four chose to pursue a co-terminal degree with the undergrad major being physics. The student classified as undeclared, stopped out of Coleman after his second year to start working; if and when he returns, he will most likely declare a degree in computer science. Of the three rated as *unsure* about majoring in engineering, two chose non-engineering majors and one chose civil engineering. Of the four

who were *mostly sure* about majoring in engineering, three chose engineering, while one chose non-engineering undergraduate major. Of the eight who were *positive* about majoring in engineering, six chose engineering majors, with one student still undeclared.

Many students at Coleman begin their undergraduate careers unsure of their major. Among those who describe their strong interest in engineering early in their college experience, many soon became ambivalent, either because coursework was more difficult or boring than they had expected it would be, or because they discovered options they had not previously considered. Students describe subject matter in pre-engineering classes that they find unappealing, professors who fail to engage—or even fail to attempt to engage—their students, and the tedium of solving problem sets nightly. In interviews, four of the eight students who entered Coleman positive they would major in engineering found themselves later either choosing another major or choosing a field within engineering that they had not previously considered. A fifth student who entered Coleman positive she would major in engineering switched to a mathematics-related major.

At Coleman, attrition was sixty-six percent among those *unsure*, twenty-five percent from those *mostly sure*, and fourteen percent from those *positive* about majoring in engineering. In other words, the less positive a student was when entering college about majoring in engineering, the more likely it was that student would choose a major other than engineering. So, although the attrition rate from undergraduate engineering within our sample was twenty-seven percent overall, attrition varied based on initial confidence about majoring in engineering (Table 3).

Table 4. Summary of MT Students' Majors Mapped Against Their Level of Exposure to Engineering Before College and Intention to Major in Engineering (n=17).

	Engineering (n=17)
Exposure	
Low	10
Moderate	5
High	2
Intention	
Unsure	8
Mostly Sure	2
Positive	7

Students at MT also wrestled with whether to major in engineering. MT's students report the same ambivalence in their choice of an engineering major that Coleman's students describe. MT students express fatigue, frustration, and boredom with their classes, professors, and heavy loads of homework. One female participant even asserted that she wished her professors could wait until she got into her major to kill her interest in her college studies.

In fact, survey data reveal no statistical difference between students at Coleman and MT in terms of their decisiveness about majoring in engineering (n=76, chi square=1.95, df=1). Additionally, students at MT demonstrated similar levels of exposure to engineering before college as did Coleman students, with ten of seventeen (sixty-one percent) MT students

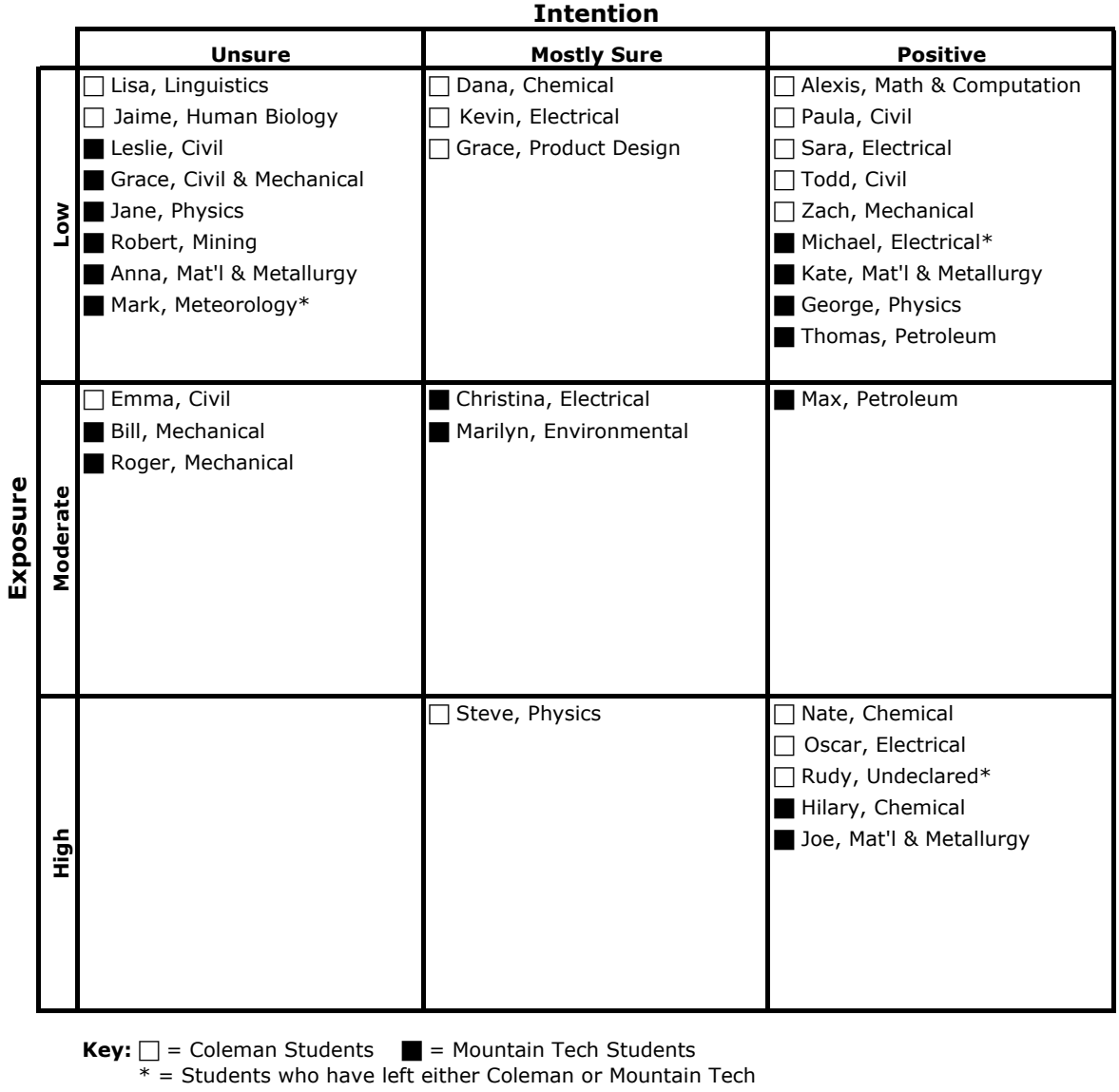
reflecting low exposure to engineering. Considering that MT provides few options for students who do not major in engineering, the similar levels of ambivalence to those at Coleman is surprising.
Although some ambivalent MT students opt to earn engineering degrees, that is not necessarily good news for engineering. Several of MT's participants in this study are close to completing engineering degrees, even though they remained ambivalent about the field and their choice; these participants report being unlikely to practice engineering or to practice for a short time before exploring other options. Strikingly, a high percentage of the students who fit this profile entered MT unsure of their intention to major in engineering.

Eight students at MT were clearly unsure of their intention to major in engineering; two were mostly sure, and seven were positive that they intended to major in engineering. At MT, of the seventeen students included in this discussion, one (low exposure, unsure intention) left MT after the first year for another institution in the state to pursue an earth science degree (low exposure; unsure intention). Another left MT after the second year for a comprehensive institution in another state to major in electrical engineering (low exposure; positive intention). Note that MT evidences lower overall satisfaction than Coleman on annual surveys ($p<.05$). This could be reflective of those students who feel constrained to study engineering not because they love it, but because there are few alternatives.

These data have limitations. First, while *exposure* ratings were based on consistent criteria, they were made *post-hoc*, after analyses of interview transcripts. These ratings reflect students' words and the content of interviews, but students themselves have not made the designations we inferred. The *intention* determinations were also extrapolated from interviews, which took place in the spring of the first year. We know that some students' intentions began to shift as early as the first few weeks of the fall term, but we were unable to probe their perspectives until spring. As with most qualitative data, our interview sample is small (n=32). We have tried to find evidence in survey data (n=76) to reinforce themes that emerged qualitatively.

Conclusion: Should I Stay or Should I Go?
The data we have presented capture an element of undergraduate experience that has not been previously examined. We have explored students' explore to engineering at the beginning of their engineering studies, and their intention to major in engineering. Taken together, these two "variables" result in the picture in Figure 1. Notice that most students fall under *low exposure-positive intention*, followed by *low exposure-unsure intention*, then by *high exposure-positive intension*. These distinctions may be important in terms of thinking about types of early engineering experiences and advising the various groups might most benefit from in making up their minds about majoring in engineering.

Figure 1. Students' intention to major in engineering mapped against their exposure to the engineering profession prior to entering college (Coleman n=15 | Mountain Tech n=17).



While research literature discusses that students waiver in their decisions about their majors, few have studied what this looks like from ground level, particularly in terms of students considering engineering. Our data suggest that students who look like and act like engineering students may, in fact, not be at all confirmed in their decision. Because the course requirements for engineering majors nationwide are so high, students interested in engineering must progress steadily through the requirements even as they contemplate whether to major in engineering; otherwise, they "fall behind" and lose the option. We see several implications.

We would like to look more closely at the experiences that prompt students to question their decision to major in engineering. In fact, forty-nine percent of 76 students in our sample at MT

and Coleman, who were surveyed in their junior year, reported having doubt at some point that caused them to question whether to major in engineering. When checking off reasons for the doubt (multiple responses allowed), forty-four percent of the responses related to classroom instruction. Interestingly, when asked about experiences that prompted students to confirm their decision to major in engineering, eighty percent of responses pertained to classroom instruction. Also of note, while only six percent of doubt was generated by faculty interaction; faculty interaction that confirmed the decision to major in engineering comprised eleven percent of responses, nearly twice as many.

In engineering education research, when students are asked their intention to major, rarely is the strength of their intention probed. The underlying assumption seems to be that students who are taking engineering courses and who express an intention to major in engineering are intending to major in engineering. Our research calls into question this assumption. We believe that one possible implication is that undergraduate engineering attrition data related may be over-reported, since many students who have expressed an intention early on (because they have to in order to keep the option open) may in fact be holding engineering as only one of several options—of which, engineering may not even be the most preferred.

The assumption that students who look and act like engineering students are engineering students may also be held among engineering faculty and administrators. We might ask, when do engineering students come to "belong" to the department or school of engineering? Students struggling to gain exposure to the discipline and profession would likely benefit from genuine contact with engineering faculty, engineering coursework, and engineering-experiences early on. In our interview transcripts, students highly valued engineering survey courses that provided overviews of engineering, faculty interaction, and any engineering-related experiences that they could get to help them decide whether to major in engineering. Such experiences were relatively rare, however. If survey courses limited enrollment; students had no natural occasion to visit with faculty. Furthermore, for many students, taking engineering content courses early meant taking them before pre-requisite courses. Students nevertheless did take engineering courses early on, but doing so often led to course overloads and increased stress.

While students were entrepreneurial in their seeking out engineering-related experiences, they simply did not have a lot of time during the term or before they must declare a major to sample too broadly or deeply. Course demands are simply too great. As a result, students generalized a lot from the singular experiences they did have. An MT student who felt ignored when he tried to get program information in the mechanical engineering office gravitated to another major. At Coleman, a student who felt ignored in mechanical engineering headed for another, non-engineering, degree option. Students who experienced poor teaching in pre-engineering courses often generalized the experience to engineering, and some began contemplating alternatives. Most students recognize that pre-engineering courses may not be reflective of engineering. But some among these students, feeling brutalized by the workload and content demands, decide that the wait is not worth it and migrate out. Students who have a boring research experience or unfulfilling internship also consider other majors. Conversely, a single positive interaction, excitement about a course's teaching and/or content, or an energizing internship can in itself cause a student to confirm his or her choice to stick with engineering.

For only a handful of students (n=5 total, the five students in the bottom right hand quadrant of Figure 1) at Coleman and MT, the decision to major in engineering was natural and unquestioned. Those who march steadily forward without seriously examining options within or outside of engineering are anomalous within our sample. Most students actively explored alternatives, and many really struggled. Nearly all students actively sought out engineering-related experiences to help them decide. Some actively explored non-engineering alternatives through coursework and extra-curricular activities. We were impressed by students' thoughtful decisions, which often involved honest self-examination of their interests, skills, and life goals.

This research contributes to the body of literature relating to how environmental effects of classroom instruction, departmental culture, and institutional structure influence students' decisions to major in engineering. Students in our sample by and large wanted to get excited about an engineering major. Some did get excited, but most did not. For some, that was mere disappointment. But others gravitated to other majors where they were excited by course content and had better opportunities for faculty interaction. Our data suggest that students' decisions whether or not to major in engineering are malleable. This provides both challenge and opportunity for those seeking to increase the numbers of undergraduates who complete degrees in engineering. If our initial analyses are borne out through further study, we believe that important but relatively minimal changes in classroom instruction as well as institutional structure and outreach could tilt the odds of students' declaring an engineering major in favor of doing so.

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