Fall 2013

Degree Program Changes and Curricular Flexibility: Addressing Long Held Beliefs About Student Progression

George Dante Ricco
Purdue University

Graduate School ETD Form 9
(Revised 12/07)

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By George Dante Ricco

Entitled
Degree Program Changes and Curricular Flexibility: Addressing Long Held Beliefs About Student Progression

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

Matthew Ohland
Chair

Robin Adams

Monica Cardella

Matthew Huber

To the best of my knowledge and as understood by the student in the *Research Integrity and Copyright Disclaimer (Graduate School Form 20)*, this thesis/dissertation adheres to the provisions of Purdue University's "Policy on Integrity in Research" and the use of copyrighted material.

Approved by Major Professor(s): Matthew Ohland

Approved by: David Radcliffe 07/26/2013
Head of the Graduate Program Date

DEGREE PROGRAM CHANGES AND CURRICULAR FLEXIBILITY: ADDRESSING LONG HELD BELIEFS ABOUT STUDENT PROGRESSION

A Dissertation

Submitted to the Faculty

of

Purdue University

by

George Dante Ricco

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2013

Purdue University

West Lafayette, Indiana

ACKNOWLEDGEMENTS

Matthew Ohland for his infinite patience and mentoring. He gets two sentences for being so fabulous. Okay, he gets three sentences. Monica Cardella for being a fantastic spiritual adviser and putting the final nails in the coffin. Russell Long for all of the data magick worked throughout the years, mentoring, and professional development. Robin Adams for waiving me into engineering design and being a positive entity. Marisa Orr for mentorship and reminding me to finish. Corey Schimpf for being a great friend and colleague. Matthew Huber for years of intellectual guidance, null models, and philosophical constructs. Demetra Evangelou for pushes in the right direction. Eugene Jackson because Goffman is a pain but he uses examples. Dan Mroczek for teaching me hierarchical linear models. Monica Cox for reminding me to be myself but put on a clean shirt. Alice Pawley for being Die Doktor Uberfrau. Brent Jesiek for insights. Loretta McKinniss for never dropping the ball.

Nichole Ramirez for being a good friend, workout partner, and forgiving officemate. Michele Strutz for always being positive. Noah Salzman for being generally unaware of his impending doom from collapsing books.

Stephanie Polliandra Nelson for being a great sister and for care packages full of love.

My heterosexual Lagomorph companion and great friend, Ms. Sadie Lovington Nibblesworth of Hoppingtonshiretonbridgeportburgville upon Northernlivingroom.

Doctor Rod Flannary, Patricia Blackburn, and Sherri Manny of Purdue University Student Health.

My parents, Samuel and Jeanette Ricco. They had to deal with me for the first eighteen years. I think that is why they're old now.

Emily Ohland for treating me like a son on many occasions.

Jerry Kalal and the staff of K.D. Coffee Shoppe for thousands of espresso shots and an office away from campus. Greyhouse for being a distant runner up.

Gerald Krockover for originally recruiting me to Purdue. Suzie Schilling for keeping my application packet together. George Bodner for sage advice.

To the professors who got me out of UC Santa Cruz. James Gill for petrology training. George Blumenthal for four vectors. Raja Guhathakurta for galaxy advice. Steve Vogt for mentoring and exosolar planet knowledge. Darrell Long for doing the right thing. Doris Ash for being an ally. Frederick Stein for science education training. David Belanger for positive encouragement. Frederick Kuttner for being a great mentor. Everyone at UC Berkeley's science education division for wise advice.

The bands Tool, Morphine, Apathy, OutKast, and Razed in Black, for being the continuous soundtrack to my life. The Queers, Reverend Horton Heat, My Life with the Thrill Kill Kult, and TSOL, for providing many nights of live entertainment. The Black Sparrow for being a horrible hipster bar. DT Kirby's for dozens of midnight Chicago dogs.

NSF grants 0935157 and 0969474.

TABLE OF CONTENTS

Page

Page

Page

LIST OF FIGURES

ABSTRACT

Ricco, George D. Ph.D., Purdue University, December 2013. Degree Program Changes and Curricular Flexibility: Addressing Long Held Beliefs about Student Progression. Major Professor: Matthew Ohland.

In higher education and in engineering education in particular, changing majors is generally considered a negative event - or at least an event with negative consequences. An emergent field of study within engineering education revolves around understanding the factors and processes driving student changes of major. Of key importance to further the field of change of major research is a grasp of large scale phenomena occurring throughout multiple systems, knowledge of previous attempts at describing such issues, and the adoption of metrics to probe them effectively. The problem posed is exacerbated by the drive in higher education institutions and among state legislatures to understand and reduce time-to-degree and student attrition. With these factors in mind, insights into large-scale processes that affect student progression are essential to evaluating the success or failure of programs.

The goals of this work include describing the current educational research on switchers, identifying core concepts and stumbling blocks in my treatment of switchers, and using the Multiple Institutional Database for Investigating Engineering Longitudinal Development (MIDFIELD) to explore how those who change majors perform as a function of large-scale academic pathways within and without the engineering context. To accomplish these goals, it was first necessary to delve into a recent history of the treatment of switchers within the literature and categorize their approach. While three categories of papers exist in the literature concerning change of major, all three may or may not be applicable to a given database of students or even a single institution.

Furthermore, while the term has been coined in the literature, no portable metric for discussing large-scale navigational flexibility exists in engineering education. What such a metric would look like will be discussed as well as the delimitations involved.

The results and subsequent discussion will include a description of changes of major, how they may or may not have a deleterious effect on one's academic pathway, the special context of changes of major in the pathways of students within first-year engineering programs students labeled as undecided, an exploration of curricular flexibility by the construction of a novel metric, and proposed future work.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The adage most physicists learned sometime along their studies goes something like, "Physics is about unlearning what you have learned." In the pursuit for understanding the literature revolving around major changes at the college level, we discovered the inverse, that most of the problem revolves around identifying actually what it is that we know and bracing the shock of *how many holes in the framework of understanding there are.*

A change of degree program (or "*change of major*" or "major *change "*) is neither the same as nor mutually exclusive from major *declaration*. The literature is replete with papers on major *declaration* (or major *choice* or major *selection*) within and without engineering, science, and elsewhere. Identifying papers addressing major *change* and its subsequent effects on student outcomes or even a student outcome are elusive. One will certainly not find plethora of them published in mainstream journals, and even the few one will find that are more recent draw upon a significantly smaller database than MIDFIELD (the Multiple Institution Database for Investigating Engineering Longitudinal Development, a database of the academic records of more than one million college students matriculating in any major at any of the partner institutions). The MIDFIELD database and research consortium has been responsible for mixed methodological treatments of such important issues in higher education such as: furthering the understanding of the critical mass effect of women in engineering, the representation of minority students in engineering, the graduate rates of student groups to six years and persistence to eight semesters, and more (Ohland et al., 2009; Ohland et al., 2008)

We find ourselves within an increasingly pressurized state in the United States. Stuck between the perpetual chanting that “we are broke” and pulled in the opposite direction by the eternal call to bolster the ranks of engineering, divining where engineering education should go in this country, let alone how it will secure funding, remains a significant question.

1.2 Rationale

When I started working within the dataset that is MIDFIELD, I had a desire to accomplish something *great*. I imagine that an introduction to such an accomplishment would have read something like,

> “This is a very great book by an American genius. I have worked so hard on this masterpiece for the past six years. I have groaned and banged my head on radiators. have walked through every hotel lobby in New York, thinking about this book and weeping, and driving my fist into the guts of grandfather clocks”(Vonnegut, 1981).

As a number of years had passed and I had yet to hear minstrels sing songs of my accomplishments throughout the world of engineering education, I surmised that perhaps accomplishing *something*, without the greatness, would be of key importance to my degree path. I realized that pulling upon my background and playing towards my strengths may help me make heads or tails out of just *what was happening here* within a dataset too large to really understand in one fortnight. So, I did what any graduate student in my position would have done, I immediately attempted to solve any and all problems within the research cluster and subsequently failed. I bumped into numerous problems too big for my skill set and others that crushed my ever-shrinking ego. Along the way I came to appreciate three core values from my time in data mining infrared data from satellites for Earth scientists:

1. Both time-variant and time-invariant digressions are important.
2. Both the position and the trajectory are important.
3. Data should be organized and analyzed on the lowest level possible

When translated into the world of education, the three listed above end up looking something like:

1. Both time-variant and time-invariant digressions are important.
2. The outcome matters, but so does the pathway to get there.
3. Study course-level data for individual students to understand much of the student experience.

Without devolving into a literature review, I spent nearly two years looking at various ways researchers in my fielded treated the above large scale topics, and they were fairly depressing. The first of the three can be framed by nearly all of Astin's early papers where he calls for a strong separation and understanding of *longitudinal* versus that which is *cross sectional* data(Astin, 1970a, b). The plague of *cross sectional* data being used across the spectrum of education research is not a new topic, but the solution to this certainly isn't easy (Astin and Lee, 2003). The idea of the construction of a publically available data set (or "unit records system") storing vast amounts of student data makes some administrative groups cringe and fans of privatization of public education rejoice in the guise of "accountability" (Educational Testing Service, 2008; State Higher Education Executive Officers (SHEEO), 2005). Of course, coordinating such a task among states is nearly impossible without a federal mandate (and federal funding) and given the unpopularity of national testing policies such as those laid out by No Child Left Behind (NCLB) and the complete lack of coordination or even misinformation at the college level makes it even more daunting. Left to my own devices, I decided that solving the large scale problem of determining which types of data systems would work for all fifty states across higher education is better left to large acronym organizations whose importance seems proportionate to the lengths of their names, such as the Data Quality Campaign (DQC), the Council of Chief State School Officers (CCSSO), and the American Association of Collegiate Registrars and Admissions Officers (AACRAO).

1.2.1 So What Can Be Done

Within the confines of my large scale goals, I identified three types of studies that could be done and would perhaps lead to some sort of interesting revelations of large-scale phenomena:

1. Student major changes.
2. Semester enrollment patterns
3. Course level analysis of a small segment of required courses

The first study I proposed would study the overall *time to degree.* This study would take off where previous MIDFIELD work had left off, and probe time to degree throughout *multiple degree changes.* This would be accessible, build off of previous work, and was within the grasp of a graduate thesis. Furthermore, the concept of *choice* from a philosophical viewpoint interested and still interests me. Questions such as "which groups of students finish faster – those in first year engineering (FYE) or those not in FYE degree programs?" strike at the core of engineering education, and have the power to develop into larger qualitative or mixed methodology studies. With a strong knowledge of which students finish faster, administrators at MIDFIELD partner institutions could make more informed choices in guiding students through advising programs.

The second study would be an interesting expansion of work outlined in the literature review of the nascent field of large scale analysis of student core course progression. Administrators may want to know just how much *flexibility* a core group of classes contains, and the net contention of students navigating or exercising that flexibility (depending on one's outlook). For a given major, a student may want to know just how likely he or she is to graduate within a certain time frame if the rules aren't necessarily followed to the letter. Also, administrators would benefit from a large scale point of view where they can see all eight semesters' coursework laid out in front of them, along with a map of just how many students are finishing each semester *by the book*.

The third study upon which I embarked involved a hierarchical treatment of student grades in three core courses: physics I; calculus I; and chemistry I. In the zero-order model, also called the null model in some circles, a colleague of mine and I discovered that the variation in grades of these courses has a noticeable component of the course section in which the student enrolls (Ricco et al., 2012). While this type of result speaks to the anecdotal evidence academics provide in casual conversation and the rants of many students complaining about their grades, I felt it was beyond the scope of this thesis. I mention this work here to simply help *frame* that this thesis revolves around large scale issues of *student choice*, how those choices affect large scale parameters such as enrollment times, and what types of novel results can be gleaned (if any) from them.

1.3 Overview of the Rest of the Thesis (Forecast)

Leaving the minutiae for the methodology chapter, allow me to explain briefly explain what sorts of data scaling is involved here. The first study revolved around constructing a dataset from MIDFIELD involved with major decisions, as such, every time a student changed a major that is recorded is available, and every time there is a shift from one to another, that is indicated as a major *switch* or *change*. For nearly all of my results, the motion of students *into* and *out of* a FYE program is not counted as a major change.

Indeed, the majority of this work revolves around the nature of major *choice,* what types of *major choices viewpoints* or *philosophies* exist in the literature, (here's a hint, there are only three major paradigms,) what switching majors more than once looks like, and large scale degree completion and *flexibility.* To be perfectly frank and ruin the surprise, switching majors multiple times does increase one's overall time to graduation, and even though students exercising great deals of *flexibility* seem intelligent on paper, there is an inherent penalty for being crafty or seeking a broader education. Whether one looks at it from an overall time enrolled in years or chooses to use a more dimensionless parameter such as number of terms enrolled, those who switch majors and exercise flexibility take *longer* to complete their degrees.

Furthermore, something interesting occurred while in the process of analysis. I noticed that little, if any, research on time to *fail* had been performed in the past. Of course, *persistence* rates to *X number* of semesters or quarters or terms have been used for decades, but as far as major declaration and changing is concerned, looking at the effect of switching majors on *how long will it take a student to fail* has not even been seriously proposed in the field of literature. Part of this may be that the notion of studying how long a student takes to fail may not be the most pleasant of topics, but in the current political climate, knowing how long a student takes to *graduate* versus how long a student takes to drop out are both factors lawmakers and taxpayers would like to know. An inquiring governor of a cash-strapped state may want to know if his policies are causing students to drop out of college sooner and move to trade school or if they are staying around longer and attempting their hand at something they cannot finish.

Finally, major change studies in the classic literature tend to revolve explicitly or implicitly around the notion that universities *want students to find the right place* and, therefore, succeed. To that end, major change studies probed here often have an academic advising bent to them. Often times, the primary investigator is a dean or former research faculty member attempting to help solve a problem of too many students succeeding at too low of a rate. The faculty member realizes that there are, indeed, programs within his or her institution to prevent attrition from majors. Then, the faculty member realizes that these programs are less effective than they should be because they are: overstressed (with adviser-to-student ratios of 250:1 or more); in league for some structural changes to deal with changing student populations and academic demands; and/or attempting to mitigate systemic failures of the university or college that are particularly rare, (such as in the case of one particular institution that was overenrolled in one class year by *one thousand students*)!

1.3.1 Delimitations and Limitations

The first set of limitations is the most important. Having presented on MIDFIELD work a number of times over the past four years at conferences, allow me to reiterate what I say at every presentation. MIDFIELD is limited to what the schools provide, and I trust the data they provide us. The first part of that last sentence is important, and the second part is mission critical. At the end of the day, I trust the numbers I receive from partner institutions. One of the most prominent examples in this study of this limitation is that I only know a major is switched at the boundary of a term! If a student changes majors within a term, I simply do not know because none of the MIDFIELD schools retains that data.

MIDFIELD is limited by the years of the data provided by the schools. On the topic of time, MIDFIELD is also current, but must be pared down to allow students *time to graduate*. In other words, while some schools have already provided us 2013 data, I will not compile and use students who matriculated in 2013 as part of any study on *graduates* for a number of years since those students have not had ample time to graduate.

MIDFIELD is limited by the number of schools in more ways than one. I have a fixed number of schools, and that itself is a limitation. As an example, I have a number of schools that is *nowhere* near the theoretical requirement for *complete* hierarchical data analysis. That is a brief way of saying that if one were to perform a hierarchical linear model (or multi-level model) of MIDFIELD data using the schools as a higher level order, there would have to be adequate room for dimensional reduction on the level of the number of schools and the effects observed would need to have some strong parity to be statistically significant.

The location and composition of MIDFIELD schools and the demographics they serve are of prime importance as well. The MIDFIELD institutions were originally dominated by schools in the Southeast with flagship engineering programs. The balance of demographics within MIDFIELD is anything but homogeneous, with two HBCUs in set. The balance of engineers to overall population among the schools is not constant through MIDFIELD. While these certainly aren't de facto negatives, these limitations help us understand how much I can extract from comparing one school to the next.

The primary *delimitations* of the study help refine certain limitations to make them manageable for the purposes of this study. Specifically, they include: first, the choice of a constant time frame for the entire study in order to ensure parity and an appropriate allowance of time for students to graduate; second, a refined sense of major choice that excludes moving in and out of first year engineering (explained at length in the methodology section); and third, the choice of the dimensionless value of term instead of quarter, semester, or chronological time, which has its own benefits and introduces unique problems.

1.3.2 Definition of Key Terms

Here are some key items that must be understood:

Change of degree program or change of major or major change: the act of having a physically recorded major on file with the register and then having this status switched at the registrar from one term to the next.

Persistence: graduation or continued enrollment as defined in the research context. Example one – *persistence to eight semesters* refers to being enrolled for eight semesters. Example two – *persisted* means *graduated*. The term persistence is defined in every instance here.

First year engineering: any program officially recognized by the university for first year engineering students that is required for degree advancement/completion. The program can consist of formal courses or introductory work, but must be listed in name by the university's engineering program and have some requirement beyond a common engineering core.

Term: a physically enrolled quarter or semester or trimester. This goes without saying but includes summer enrollment as well.

Flexibility: the degree to which students can *skip or substitute* courses listed as required in the published curriculum for their *final* degree program. Example – a student who graduates in civil engineering is *assumed* to have taken all of the required courses listed on file with the university's registrar for civil engineering. Any deviation from that in the actual record of what that student took will be considered as the student exercising *flexibility* in circumnavigating the degree requirements.

CHAPTER 2. LITERATURE REVIEW

2.1 Major Declaration and Changing as a Critical Life Choice

As a guide for reference, I have included the attached table (Table 1) here as a guide to some of the more frequently cited papers I discovered upon my journey. While there are some interesting papers with decent student sets, few define their own set of major guidelines. Almost all papers concerned with major change allow the host institution's registrar to be the sole arbiter of what constitutes a major change. The exceptions to this rule either define their own sets of major groups for statistical probing, bin students into groups based on frequency of changes, establish a methodology for differentiating between a more or less *significant* major change, or some combination all three (Elliott, 1984; George-Jackson, 2011; Gordon, 1981, 1992; Theophilides et al., 1984). In general, I found that papers followed three overarching themes: first, the choice of a major is a significant academic decision; second, changing majors is a significant academic decision replete with its own problems; and third, understanding major decisions aids institutional policy and advances educational theory. The degree to which these papers agree or disagree, as well as the coherency of their treatment of major related issues cannot be overemphasized.

Within the realm of student retention within a major, the concept of where to focus interventional energies is also of utmost importance (Willcoxson and Wynder, 2010). Willcoxson debated whether retention programs at the undergraduate level for business students should be directed at entire swaths of faculty or more heavily towards risk factors within the majors themselves.

Of course, the solution to the problem is highly difficult to solve, or as Willcoxson puts it, “Different risk factors exist for attrition in different majors within the same faculty” (p.177). Selecting a major that is more career specific leads to greater student retention (Allen and Robbins, 2008; Bean, 1980), which could attenuate the need to address systemic issues.Willcoxson’s work supports the idea that those outside of engineering are within a system that does not provide much clarity of direction on major choice. Business students locked into a career pathway such as accounting have a very (seemingly) direct pathway. Willcoxson found that students within focused majors (accounting) had a lower likelihood of leaving even if their general reason for attending university was less clear than their peers. This also may explain why shifting between engineering fields or from ENGR to other fields is viewed as deleterious and why career path definitions vary so greatly across boundaries. Willcoxson proposed that students who initially possessed a strong direction towards a certain major were “more likely to leave” after changing (p.178). Also, simply the extent to which a major is labeled “generic” may or may not contribute to a lack of student direction. The application of this work has implications for studies of the arts, as well, since the arts have traditionally fewer defined career pathways.

Willcoxson further expands upon the differences in student attrition (Willcoxson, 2010) in a study of semester differences from year one through year three in an undergraduate student population. Students tend to develop a “needfinding” approach to education as they progress through their degree programs, shifting from searching for resources relating to advising and more basic types of academic support in their early years to those related more directly to academic success. As Willcoxson notes, “As student progress in their education (2+ years), attrition is associated with an increasingly more narrow range of factors” (p.627). Attrition in the second year is “primarily related to personal aspects - health, finance, social integration, clarity of career direction and self-efficacy in relation to academic capacity” (p.633). “Third year students… have largely come to terms with what is offered and expected in teaching and learning” (p.633). Across all years, Willcoxson concludes that “Those seeking to decrease attrition in ALL YEARS OF STUDY might focus on building students' academic expectation" (p.627).

Allen's work in 2010 is based on foundational assertions developed by Allen in 2008 on major choice congruence in longitudinal studies (Allen and Robbins, 2010; Allen and Robbins, 2008; Allen et al., 2008). Allen's primary findings in 2010 were that students were significantly less likely to switch majors when their interest major congruence factor remained high, are more satisfied within their major, and that students are more likely to graduate in a "timely fashion due to not changing majors." Strangely enough, interest major congruence did not predict first year performance, but had a strong effect on the timely attainment of a degree even controlling for first year performance.

In 2008, Allen's study of over 50,000 students in 25 four-year institutions developed a theory of persistence to relate first-year performance to third-year performance. The qualitative component of the study used came from Holland's work on a things-people axis, simplified to a two-axis methodology (Prediger, 1982), and offers two primary assertions: that major choice is affected by a "pattern of interest" (p.63); and that student satisfaction or success with a major is affected by how interests align with environment. One of the "patterns" defined by Allen is major choice, for example, "Students who change majors are more likely to take courses not necessary to graduation" (p.63). Given the historical nature of the crowded engineering curriculum, Allen's postulates are supported by the observation that 76.5% of engineers in the study persisted to three years. Allen cited Kramer's study where 75% of a cohort changed their majors and concluded this was to better suit their interests (Kramer et al., 1994).

Switching a major has delayed and potentially deleterious consequences to a student's career. For instance, Allen names the "latency effect" of a major switch as the effect observed when students switching majors continue to take courses in the previous major and vice versa. This hypothesis has longstanding consequences for the development of coursework metrics on multiple levels. Studying the time frame in which students complete a defined, first or second semester's curriculum may be frustrating for students who have switched majors, as it may have been impossible for students to take required courses in a normative or sequential order. The nature of this “latency effect” is further exacerbated by inflexible engineering curricula at various schools that require sequential progression.

The seminal study by Theophilides probes a 1978 cohort of N=2147 freshmen for a large public residential university using the Student Information Form developed by Astin and CIRP, and then a follow up questionnaire in 1979 (Theophilides et al., 1984). Classifying student pathways as “no change,” “early change,” “late change,” and “constant change”, they predicted changes within 45.5% using a step-wise algorithm. Within their study, 44.8% of students reported changing their major in both their freshmen and sophomore years, thus they were considered “constant changers.” The main conclusion reached is that non-changers had the highest GPA, higher levels of institutional and goal commitments, fewer non-classroom contacts with faculty and university staff concerning intellectual matters, and also reported a low likelihood for changing their major field prior to matriculation! While early changers had the lowest SAT scores, they had a high pre-college likelihood to change majors and tended to perform well during their first year. Of students studied by Theophilides, 23% reported no change in major in the first two years, 15.6% changed early (freshman year), 16.6% were “Late changers” (sophomore year), and 44.8% reported changing their major in both the freshman and sophomore years {“constant chaners”).

The work of Titley at the University of Colorado in the 1970s is some of the earlier work in major selection, which he developed over a long period (Titley et al., 1976). Studying a selection of students (N=808) who changed majors from anything other than “general studies.” After a major switch, Titley interviewed about their job and career aspirations that they were headed towards in both their old and new major choices. Titley divided the student descriptions of their old and new trajectories into “Level I” and “Level II” specificities, where Level I changers are unable to state a specific job or career in a major trajectory, and Level II changers could identify a stated career, with knowledge of further preparation such as graduate studies required for career advancement.

Titley noticed two coupled phenomena: the students who switched later in their careers seemed to have less awareness about career direction than those who switched earlier; however, all students became more specific about their career directions after a change no matter when the major change occurred. Making connections to the work of Osipow on career theory, Titley notes that even outstanding students encounter difficulty with required curriculum courses in their major. These students appear to be similar to students with achievement problems (Osipow and Fitzgerald, 1995).

Another of Titley's works studying 2451 student records and 648 students with yearly surveys over two years at Colorado State University studies the effect of changing majors during the orientation process. (Titley and Titley, 1980) Students could choose whether to declare a major upon matriculation, and were given a chance to switch majors during the orientation process. Titley notes that even though the choice of major is fundamental to the academic enterprise, the "end game" issues of career pathway and retention seem to be much more surveyed by his colleagues. He follows in that vein of thinking by declaring a major progression to be fluid, and not some precipitous drop or binary system, as research often times "seems to assume that a student's selection of specific major represents a fully crystallized choice rather than a mere manifestation of the normal trial or exploratory phase of this developmental span" (p. 293).

Of the students who changed, some interesting patterns emerged. The students who declared a "general studies" major changed majors during orientation at a rate of 8%, and around 2/3 of those who choose a major decided to keep their initial choice. The problems of the badly defined state of switching majors is compounded by the "current push of vocationalism" that causes students to choose majors earlier. Students are not the only ones to blame according to Titley, as faculty and staff tend to think that major undecidedness is a sign of "academic ineptness" or "negative indecisiveness" (p.297) instead of a natural developmental process. Even the curriculum has issues that deliberately set back students as, "curriculum designs that feature rigid and extensive area-related requirements in the first two years preclude exploration and often lead to a setback in time and in some cases feelings of failure or indecisiveness when a given student shifts to another major" (p.297).

In the six-year follow up to Titley's original study at Colorado State University, Titley further waxes philosophically on the issues around switching majors during orientation (Titley and Titley, 1985). Titley is more resolute than in his original study, concluding, "it is a serious error to assume that entering college freshmen are either decided or undecided about a major" (p.466). Also, when students chose their major upon matriculation and subsequently did not change their major during orientation, Titley believed that "the change of major and attrition were related to the degree of subjective certainty by these students" (p.465). The researchers noted that the 43% rate of attrition among the students surveyed was not related to their degree of certainty of their choice of major. That being said, among those who graduated, the major rate of change for uncertain students was 70%, 58% for tentative students, and 38% for certain students. The "general studies" students had more than a 70% chance of graduating when they chose a specific major, meaning that when students matriculate into general studies and finally decide to commit, they have a strong chance of graduating. The net contention of these results according to Titley is that the choices students made about major during orientation are just as unstable as the initial choice of major upon matriculation.

Kramer's study is one of the only studies of multiple major changes across multiple cohorts that exists. Kramer used data of Brigham Young University students from 1980 through 1988 who graduated. While "on the average, 47% of the graduates in all of the cohorts selected the major they ultimately graduated with at the time they applied to the university" (p.90), students who did not indicate a major upon matriculation made fewer major changes on average throughout their academic career. Also, the vast majority of major changes were external to the college into which the student first declared. Kramer concludes that switching majors does not substantially increase the time to a degree, because while the average number of semesters to graduation increased by more than two from 1980 to 1988, the average number of major changes per student did not. In fact, other than 1980 where the average number of major changes was 1.5, every year before 1988 had a higher rate of average major changes per student! The timing of the change is important, as 32% of changes took place in junior year and 13% in senior year.

> "Another aspect of the first research question concerned a match between the major declared on the college application form (which became the first semester major) and the major at graduation. Somewhere between 42% and 56% of the graduates in any given year of our study cohorts had a match between their application major and their graduation major. On the average, 47% of the graduates in all of the cohorts selected the major they ultimately graduated with at the time they applied to the university" (p. 90)

Micceri's work is relevant to MIDFIELD since it analyzes seven cohorts of FTIC students at the University of South Florida. At USF during that time, students were not allowed to change majors from their matriculation major until being enrolled for two semesters. Among the students who graduated with a bachelor's degree, there is little difference in overall number of years enrolled between those who never switched majors (4.80 years), those with one change (4.82 years), those with two changes (4.88), and those with three or more changes (5.03). Micceri concludes that "The data do not suggest that a greater number of major changes substantially increase the time to degree" (p. 4).

In a study of Michigan State University students from 1976 through 1977 and N~14,000 students, Krupkka noted that 75-80% of students have declared a major upon matriculation and approximately 75% of those students will change at least once (Krupka and Vener, 1978). Noting systemic problems, "we feel that current programs, procedures, and organizational structures in most large universities, however, are haphazard and inefficient in regard to facilitation of a student's final career choice. Too much is left to chance" (p.112). Students with no major preference receive counseling advice that is not under pressure to bolster retention numbers for any particular major or college.

Krupka found that students who had indicated “no preference” upon matriculation had an average major change number of 1.2 students whereas everyone else had a value of 3.0! The key bone to pick is that the status of “no preference” is not the same thing as a student who cannot make up his mind. Krupka concludes that: all students should be in “no major” upon matriculation; general academic advisers should be trained in career counseling; other career education bureaus should be publicized to the students; and that career education course credits should be developed.

George-Jackson’s recent paper studying 16,850 students who finished within six years from five public land grant institutions most closely resembles the data available within MIDFIELD (George-Jackson, 2011). Adding to the voices of previous authors, George-Jackson correctly asserts “There is a gap in the literature in understanding what majors students switch to after initially majoring in a STEM field.” (p. 151) While men in their study did declare a STEM major at a much higher rate than women did, women switched majors earlier than men and finished earlier. Women may have finished more courses than men did and/or “completed more homework assignments.” p. 167

George-Jackson raises some valid concerns about the treatment of women within quantitative studies. For instance, she defines four categories for probing: the physical sciences, computer science, mathematics, and engineering (PSCSME); agricultural and biological sciences; health sciences and psychology; and non-STEM fields. The reason why these delineations are important is that when health science fields are left out of STEM discussions, this greatly attenuates the number of women determined to be “in the sciences.” Of course, this creates problems when directly comparing this study to others, as this definition is neither prevalent nor accepted in the education community.

Warren’s survey of major changers comes from a study of 525 National Merit Scholarship winners in over 200 different colleges, including engineering schools (Warren, 1961). Using the Omnibus Personal Inventory (OPI) personality scale, Warren divides students into “no change,” “minor change,” and “major change” categories of major change. These types of delineations are normal as even within my work, I divide some analyses into switching into or out of engineering from “anywhere else.” Warren noticed that there was no significant difference in self-role discrepancy between “no,” “minor,” and “major” major changer. “No” change is defined as a student simply making no change or making a more specific choice of major from a general, larger major field. For instance, a student in a school of business studies who switches from a general business studies degree to a more specific major within the business school would be considered a “no” change student. Changing between related fields could be a “minor change” (such as engineering and physics). A change between a broad field and a subfield was considered “no change” such as physical science to meteorology.

Those students who partook of double major changes had a higher self-role discrepancy. The only difference between those who did not change majors and those who had a “major change” was their GPA and “thinking inversion” scores. A high thinking inversion score was linked to art majors who changed more often than students in the technical disciplines, including engineers. While GPA does not protect against a major change, it does protect against a “major” major change, as high GPA students had the highest rate of “minor” major changes.

In Brown’s work of freshman major choice among students who had not declared a major, students were asked about their major choice status and career choice status (Brown and Strange, 1981). In a survey of 179 students, Brown noticed that the process of choice becomes a source of anxiety for students, and that the anxiety of undecided students mimicked that of students with a major but without a defined career pathway; thereby allowing Brown to conclude that simply pushing students into a major choice will not make them any more at ease about their academic and career futures. Brown noted that the question of “What’s your major?” is ubiquitous question on college campuses. Brown believes that universities must be careful and help students who are undecided make the correct major decision by making it more culturally acceptable to be undecided. For example, “It is conceivable that people make choices but feel dissatisfied with that choice while they are in the process of choosing. It is also plausible that some individuals are satisfied with being undecided and feel no pressure to move toward a decision” (p. 43).

Similar to Brown, at Clark University, Smith’s study of 164 freshmen in two classes noted that students who choose a major seemed better adapted to college life in general, supporting the concept that simply being able to say what your major is to friends, family, and colleagues may alleviate some stress associated with college life in general (Smith and Baker, 1987).

Another freshman study (N=1044) at a major east coast public university by Levin using a mixed methods approach of high school GPA, SAT scores, and attitudes toward mathematics and science, revealed interesting patterns among engineering students (Levin et al., 1994). For instance, Levin discovered that most students did not know that over half of engineers drop out of their major even though they are qualified to progress through their degree program. Furthermore, the nature of the engineering curriculum is misconstrued, as there is generally a “misconception of the nature of an engineering curriculum and the day-to-day work of engineers” (p.26). Even though attrition from engineering is aided by a “Lack of ability in… mathematics and science” (p.26) the effects of curricular structure cannot be disguised. Also, the effects of the current nature of curricular entanglement has not properly been surveyed. Levin’s prescription for a lack of student engagement with the engineering curriculum is to change the theoretical nature of engineering into a more applied one.

Levin discovered that among the major variables probed that gender was the least predictive of success in engineering, defined as progressing to the second year. The most predicative variable of progression to the second year was having taken physics in high school, which is a conclusion congruent with Levin’s assertions that the introductory engineering curriculum lacks an applied component and overly emphasizes mathematical skills. Lastly, perhaps one of the most useful constructs from Levin is the defining of "PERSISTENCE IN ENGINEERING" as a threshold GPA and a 2.0 minimum in core Calc/Chem/Phys courses and making it to the second year.

In a two year study at a R1 involving three engineering cohorts with junior and senior follow up surveys, Suresh used a Likert-based survey instrument to uncover patterns within "barrier" courses (Suresh, 2007). Dividing students up into different groups of persisters, Suresh classifies students as "Sailers," "Plodders," or "Struggling persisters." Sailors are students who maintain A/B grades in barrier courses with no repeats. Plodders have A/B/Cs with one or more repeats. Struggling persisters have A/B/C/D/R/R/W with one or more repeats. In core engineering courses, such as physics, calculus, chemistry, and statics, over 20% of the students in Suresh's survey repeated one or more of those courses. Suresh's primary assertion is that the key to understanding persistence is in understanding these classifications of students.

One of the more interesting conclusions Suresh maintains is that all three persistence groups did not vary in how they choose engineering or why, nor did their choice of engineering reveal an enlightened mind possessing arcane knowledge about engineering used to make a choice or not. Also, while sailers felt positively about faculty, struggling persisters did not. Students also consistently reported that when they reached an utter nadir concerning whether or not to stay in engineering, often times one person's intervention caused them to stay. Finally, the single biggest factor concerning persistence was the determination to succeed in engineering.

> "The decision to major in engineering was not always a result of informed decision making. Some students appear to have confused an interest in science and math with an aptitude for engineering. Others came in thinking that engineering would be similar to the technology-oriented preparation that they had experienced in high school. Still others were influenced by the experience of family members in engineering professions. Most of them appear to have decided on engineering school during high school, and a few just at the point when they had to choose a major on the application form for admission. Contrary to my expectation, "sailers" were not different from "plodders" and "struggling persisters" in how and why they picked engineering as a major. The

common bond shared by all persisters was their interest in and aptitude for science and math while in high School."

Lichtenstein, as Suresh, noted the effect of self-evaluation of a student and its effect to stay or not stay in engineering (Lichtenstein et al., 2009). In a mixed methods study consisting of ethnographic interviews and yearly surveys of 74 students at two universities who pursued engineering degrees and finished, Lichtenstein observed that most students were "disproportionally swayed by a single experience" (p.232) to stay in engineering. This could be a faculty interaction, a job interview, peer interaction, etc. Also, most students were unsure of their career trajectory in the future, and while a small fraction did not wish to stay in engineering (~12%,) more students were “unsure” (~44%) to stay in engineering than those who wished to stay within the engineering field upon graduation (~42%). Taking Suresh’s work a step further, the results of Lichtenstein seem to indicate that students continuously evaluate whether to stay or leave engineering, but pivotal events that induce monumental decision making do not frequently occur, as is expected from other work.

Gross’s early study of students at SUNY in 1974 discussed the engineering stereotype and how students reinforce it (Gross and Gaier, 1974). While engineering has a stereotype, Gross noted that other majors within the college appeared to do the same. The difference Gross noticed was that students who were most decided in their career trajectory tended to self-stereotype more than those who were less decided. "The most crucial factor affecting applicability here appears to be the degree of decidedness a student has regarding his vocational choice. Those most certain of their occupational choice seem more likely to fit Holland's model" (p.212). Of course, the open question in Gross’s treatment of students is the role of the curriculum on self-stereotyping.

Mikkonen’s work draws some interesting conclusions about the notion of choosing a major before matriculation (Mikkonen, Heikkila, Ruohoniemi, & Lindblom-Ylanne, 2009). Mikkonen’s three research questions revolve around how students explain major choice, how major interest develops into action, and whether or not

Krapp's theory on student major choice can be expanded upon.(Krapp, 2002) Krapp conjectured that three faculties of student major choice exist: situationalized; stabilized; and individual. In a study of Finnish students (N=536) of diverse backgrounds who choose their major before matriculation, Mikkonen extrapolates a deeper meaning of the word interest in relationship to a student's overall career. Similarly to Krapp, Mikkonen conjectures that interest cannot be decoupled from specific content, and the interest in a major is inextricably linked to the content within that particular course of study. Furthermore, long term interests can only be few as opposed to multiplicitous.

Of particular concern to Mikkonen is how a choice of major can be an informed one. The work noted a relationship between more specific majors and work paths, for instance, "Answers that included comments related to future work were more common in the answers of law and veterinary students than in those of the arts students" (p.239). Also, student confidence is always coupled to major change, irrespective of student ignorance about a fundamental understanding of the major itself.

Beggs raises questions about the ignorance of students concerning major choice (Beggs et al., 2008). In a qualitative study (N = 852) Beggs coins the phrase "strategies of indecision" (p. 382) to describe the illogical methodology used by students to choose a major. While believing that a "good" major is one that helps a student achieve educational and post-educational goals, Beggs questions the ability of young people to "use the information to make decisions about their future" (p.392).

The strongest factor in major selection was a student's interest being congruent to their choice of major, while the major course's attributes was the second strongest factor. Thus, the study concludes that students with varied interests may be more prone to switching majors. Also, five recommendations for improving major selection quality: delay the major choice; evaluate what and how we inform students about majors; speak with parents; and always consider the unique qualities of an individual institution. That being said, the weakest link of Beggs' study is that the study did that "evaluate whether the students perceived strengths and abilities required by a major match the actual strengths and abilities required" (p.392). Furthermore, no recommendations are made about an internal realignment of the major's coursework with what is communicated to the students about the major.

Leuwerke's work at a major southern university with an open enrollment engineering program used binary models based on ACT scores to predict second year enrollment patterns (Leuwerke, Robbins, Sawyer, & Hovland, 2004). The work "supports the idea that the fit between an individual's ability to master academic skills associated with a specific major… is an important determinant of major status." Also, Leuwerke notes that little is known about students who switch majors, as data about them seems to be lost or they are not tracked after a switch. Another issue at hand is that Leuwercke concludes that persistence within engineering takes many forms, and that minorities and women did not have significantly different attrition rates.

Porter's work raises the possibility that *uncertainty* in major selection is a factor students must grapple with when choosing a major (Porter and Umbach, 2006). Studying a multinomial logistic model with data from three cohorts at a selective liberal arts college, Porter concludes that after controlling for race and gender, both sexes choose non-scientific majors over scientific majors at the same rate. Major *uncertainty* tended to be more related to choosing an arts or social sciences major, while political beliefs and personality were the more consistent variables affecting major choice. Porter also noted the sparse number of major choice studies as "little has been done on student college major choice" (p.429) and that among the existing studies, they appear to be divided into mutually exclusive domains. After controlling for race and gender, both men and women choose non-science over science at the same rate. Major uncertainty is related to choosing an arts or social sciences major. Finally, political beliefs and personality are the most consistent variables within this work.

Gordon's work on advising major changers at Ohio State University represents the types of "interventions" that may be required to handle students who switch at such a fragile time in their academic careers (Gordon, 1992). Through his experiences in the "Academic Alternatives Advising Program" he used Theophilides' (Theophilides et al., 1984) descriptions of major change "types": early or first year; late or second year; and constant or both first and second year switchers. The problem of major switching at Ohio State University was not only a naturally-occurring phenomenon related to multiple factors found elsewhere, but also due to an extreme number of “oversubscribed” majors, leaving otherwise qualified students in a non-major quandary. Gordon noted that more than one thousand students in a single calendar year ended up unable to enroll in the major of their choice! Also, the 1:350 ratio of advisers:students may have worked when advising students about what major best suits them, but that system did not adequately address the more specific needs of students who believed they found the right major for them and who later discovered they had to make a second choice.

Gordon’s program rests on a firm belief that students who are out in the cold concerning a major choice and students who switch majors must receive proper interventional advising. Not only are students in “transition from one major to another… often ignored,” (p. 27) but they need “special curricular and career advising” (p.22). Gordon outlines five “flags” that should trigger a warning sign for administrators that a particular student may need special advising: students with 60+ hours without degree progress; a department admission denial; an unsuccessful prerequisite completion; undecided juniors; and those who have advanced hours and need help. Along with a better ratio of advisers:students (1:150) for a special program, the advisers for flagged students are more sensitive to course scheduling, lead group sessions on major selection issues, and guide students through a special course. In Gordon’s study, 55% of the students who were flagged for intervention graduated and 15% of them were still enrolled, meaning that the intervention process worked.

Wessel’s theory of objective and perceived major fit or commitment came from a study of 189 students (160 women) at one university that demonstrated three particular lineages: normative; affective; and continuance (Wessel et al., 2008). Affective commitment refers to commitment based on preference, and individuals with strong affective commitment are assumed to stay in their environment because they feel affiliation to it. Normative commitment refers to commitment based on obligation or duty; individuals with strong normative commitment will stay in their environment because they feel it is what they "ought" to do. Continuance commitment refers to commitment based on need and lack of alternatives. Individuals with strong continuance commitment stay in their environment either due to the costs of leaving or the benefits of staying, in relation to their needs. Adaptability is the tendency for a student to thrive in an environment that best matches his ability to read a situation, respond effectively to a change, and the ability to self-evaluate one's identity and develop "adaptive competence" (p.366) Almost endemic to Wessel's treatment of the major change is the concept of a "major-related" outcome defined as the probability of changing majors, not simply a failure to succeed or persist within a particular major.

The factor of affective commitment is the biggest factor preventing students from switching majors, while GPA and generalized major commitment were positively correlated. As expected, a student's academic self-efficacy was positively related to perceived major fit. Also, the perceived major fit of a student did not in any way explain the variance in GPA and the probability of a major change. The main sticking point of Wessel's argument is that universities and institutions may have no mechanism for boosting affective commitment to a major, or at least not an easily realized one.

Vogt in 2007 probed 713 students of all academic standings from four West Coast research universities with engineering programs in order to study determining factors in success, with specific regards to the success of women (Vogt et al., 2007). Vogt studied similar phenomena in a more focused 2008 study addressing the issue of faculty contributing or detracting from the success of students in engineering (Vogt, 2008). Both studies concluded that faculty have a critical role to play in not only the success of engineering students as a whole, but specifically in regards to major choice and attraction to a major. For instance, "Faculty may not realize the critical role they play in women's decisions to choose engineering or switch to another major… in the weed out system, withholding support is an imperative for many professors" (p. 340). In other words, if a student feels positive about the faculty and environment, then the students have greater engagement with the material, whereas “distant” faculty affect academic confidence, self-efficacy, and ultimately, all types of decisions involving major.

Vogt also noted differences between the sexes in major choice decisions. For instance, the problem of inadequate advising cited as having a greater effect on female attrition from engineering that male attrition from engineering, a property detailed by Seymour (Seymour, 1995). Seymour also noted inadequate advising or help with academics evident in 84% of female SWE switchers versus 69% for males. Women report more discrimination but it doesn't affect self-efficacy as much as men, indicating “academic resilience” (p. 356). Also, women were more integrated into academic and social networks than previously reported.

Vogt identifies a few areas where women and men may have developed ways of thriving in an environment otherwise hostile to them. Vogt’s “academic resilience” construct pushes back against the negating effects of discrimination upon self-efficacy. Vogt hypothesizes that female students’ integration into academic and social networks, properties examined by Vogt to an extent not previously expounded upon elsewhere, contribute to such a resilience factor. While other potentially detracting factors such as educational elitism (Trow, 1973) or the chilly climate (Seymour, 1995; Whitt et al., 1999) have placed obstacles in the way of the success of women in engineering, Vogt notes that strong academic qualifications of women, their confidence in their abilities, and their unambiguous academic and career choices, all have strong counter-effects.

Lewis’s work at Iowa State among freshmen male (N=691) probed large scale issues using a cross sectional metric for students matriculating in 1957 (Lewis et al., 1965). Using the Strong Vocational Interest Blank for Men and the Iowa State University Mathematics Placement Test, Lewis comes to many interesting conclusions. Congruent with modern results from the MIDFIELD group, Lewis uncovered that “these [engineering] curricula tend to lose more students by transfer than they gain,” (p.63) an observation well documented by MIDFIELD researchers in work revolving around attraction to and migration. Students who voluntarily dropped out of engineering due to academic issues (GPA below a 2.0) tended to be more closely related to those who were removed due to GPA than those who voluntarily left with GPAs above 2.0. Also, by every predictor variable on the Strong inventory, engineers and non-engineers are practically diametric opposites! Perhaps humorously, mechanical, civil, and electrical engineering students tended to score higher on the "masculine" measures than men in teaching and social service occupations. Finally, the tone of Lewis should be noted, as the generalized drop out descriptor is entitled "academic failures."

> "To both the student and the college, a transfer represents loss of time and money-whether the shift is between institutions or within a university. Perhaps nowhere is transfer a more disturbing problem than in colleges of engineering. Induced by propaganda extolling the rewards of an engineering career, many young men enter engineering programs with unrealistic conceptions both of their own abilities and interest and of the demands of these programs" (p.63).

Molnar's early work on curricular mobility at Purdue University with freshmen (N=904) took place in 1966 and involved a complex interest inventory of 204 questions normalized to a Likert scale (Molnar and Delauret.R.J., 1973). While the "overall engineering interest" scale predictor protocol came from the Aeronautical Engineering Interest Scale battery, his results seem to scale well for all engineering majors. Molnar's primary assertion is that overall engineering interest differentiated between engineers who persisted and those who withdrew altogether, but not those engineers who transferred. This of course, has strong implications for the types of students who attempt to stay within engineering but fail versus those who leave on their own accord. For example, "The fact that withdraws and transfers have similar low first-semester GPA but that withdraw have significantly higher overall engineering interest and significantly lower industrial management interest has interesting implications." Also, "Perhaps students who transfer, unshackled by as strong a drive to become engineers and not adverse to industrial management, more quickly consider the alternative of a less rigorous curriculum when faced with the possibility of termination." And, "Conversely, it's possible that withdraws, given their overall engineering interest and negative industrial management interest, "may attempt to persevere in an engineering curriculum despite the indication of possible university termination as evidenced by their initial performance in engineering" (p.56). As expected, the engineers who transferred out of engineering of their own volition possessed the lowest overall engineering interest scores, and tended to seek curriculum less theoretical or in this case, "mathematical." At Purdue University, students who transfer from engineering characteristically tend to seek less theoretically oriented curricula such as those offered in the School of Industrial Management and the School of Technology" (p. 56).

Elliott's work notes the traditional burden of degree progression being placed unfairly on the student, and seeks delineation between sets of major changers. "Historically, universities and colleges have placed the burden for successful completion of degree programs on the students" (p. 39). Elliott's sets are: those declaring a major; those who have switched once; those who switched more than once; and those who are provisionally enrolled in courses due to a low GPA. In a study of eighty students within the a college of human development, Elliott noted that those students who changed majors the most had an overall lower GPA than those who just declared and those who only switched once, but not as low as students who were provisionally enrolled, (although statistically the same after counting error). In Elliott's evaluation of a career maturity inventory scale consisting of 55 items, Elliott concluded that career maturity along could not yield a difference between major choosers.

Hand in hand with the appreciation of non-engineering professions is Osborne's desire to understand the "healthy" conditions for students (Osborne and Jones, 2011). In a paper heavy on symbolic interactionism theory that seems complimentary to Holland's theories of work related choices, Osborne outlines two basic propositions for "healthy" major choices selection: first, that healthy individuals migrate towards positive producing domains; and that healthy individuals alter domains as conditions change. Osborne's assessment of a domain manifests itself as the realm of the major itself; therefor, choosing or switching a major to Osborne is an innate and externalizable form of domain identification. This begs the question - are we encountering "healthy" conditions for our ENGRs?.

Knight's structural equation model of FTIC students at one university from 1998 through 1999 with N=2585 uses elapsed and enrolled semesters to describe a variety of effects (Knight and Arnold, 2000). After declaring upon matriculation, Knight found that 73% changes majors at least once, 27% changed twice or more; 8% changed three or more times. At least 39% of students retook one course, 21% withdrew from one course, and 37% failed at least one course. The two strongest factors in predicting time to degree were total credit hours earned and participation in the academic forgiveness program (available for non-traditional students away from college for five or more years). The most interesting result of Knight's work is that while their first model predicted 81% of the variance in semesters to degree completion, their second model only predicted 43% of the variance in total semester elapsed to degree completion, indicating that actual *physical* time elapsed to degree completion may be more difficult to successfully model.

Kresya's study of N=438 FTIC traditional students in a large, private, West coast public university of mostly undergraduates uses a logistic regression to study persistence or graduation within eight years of matriculation (Kreysa, 2006). This study demonstrated that the type of pathway a student took regarding declaring a major had a measureable effect on graduation. For instance, for non-remedial students, declaring a major increases persistence by 22% while changing a major decreases persistence by 17.2%. "Remedial" here indicates any student that at some time took a 0^{th} level or "remedial" type of course. For non-remedial students, declaring a major increases persistence by 22%, and for non-remedial students, changing a major decreases persistence by 17.2%. Whereas cumulative GPA was a strong predictor for non-remedial students, it was not a strong predictor of persistence for remedial students. Finally, for remedial students, declaring or not declaring a major was not significantly linked to persistence, whereas changing a major increased persistence by 40%!

In a study of N = 4403 non transfer students from four institutional databases at one large public urban university, Lam studied students who matriculated from between 1989 and 1993 and graduated by the Spring of 1996 with 56% women in order to study the effects of financial aid on degree (Lam, 1999). Following in the vein of Porter and Mortenson, Lam wishes to develop a better understanding of the differences between types of financial support's effect on degree progression. Lam discovers that students in the "loan only" category had the lowest GPA among all students in the university, but were the fastest to complete their degrees in terms of number of registered semesters. Students receiving loans, gifts, and on work study had the highest time to degree in terms of elapsed semesters time and students on work study receiving gifts were the fastest to graduate in terms of elapsed semesters.

Duby studied two groups of students: the 1986 cohort of Oakland University in Michigan; and the 1993 through 1996 cohorts of Northern Michigan University (Duby, 1997). Using the Pearson Product Moment Correlation battery and a graduation time frame of eight years, Duby studies the link between first semester course load on GPA, retention, financial aid, and graduation. Invoking Volkwein's work on extenders, Duby asserts that the scheduling of lighter loads has an effect on graduation. Students who enrolled in a full load of 16 credit hours were much more likely to graduate than students who registered for 12 hours. The debate between whether or not students who underload are more or less integrated into the university experience, therefor accelerating or hampering their degree progression, is left as an open question. Duby's pessimistic conclusion on the state of the Academy reveals much about his mindset,

> "How much time they spend studying versus working or socializing may be established early, so that if they take a lighter load the first term and find that they have time to spare, they may use that time to work additional hours or do other things… (Although we would like to think that they use the time to study more, that is probably not what actually happens)" (p.17).

In the College of Arts and Humanities at a large urban university, Harris and a three-member staff team provided information to students who remain undecided, (one coordinated and two, half-time graduate students) (Harris et al., 1985). His research group noticed that the students generally lacked information regarding careers and major areas of study at the university, as well as information seeking skills relevant to choosing a major. Their intense intervention technique yielded some interesting, qualitative results, including 47.4% of the students choosing majors by the end of the intervention. Harris concluded that the heterogeneity of the workshop was actually a disadvantage. Harris suggested that the divergent nature of the group provided a less supportive environment than, for example, a group of engineering students would have provided each other.

Complimentary to the work of Gordon, Steele at the Ohio State University focused on the construction of an Academic Alternatives Program (Steele et al., 1993). In particular, this program catered to a cohort in dire needs – one where a significant number were unable to access the major of their choice not simply due to academic requirements, but due to overenrollment. While the results were tenuous, the construct of their research, (including a random control group, a cohort group, and a group direct to the program,) indicated that a three hour course could help student decide a major to meet their needs.

Lewallen's follow-up to a 1989 study of the Cooperative Institutional Research Program (CIRP) longitudinal data from N=18461 students with 57.6% females (Lewallen, 1993). Using Astin's Input-Environment-Outcome model, Lewallen comes to some important conclusions about students. First, with 12.9% undecided students, Lewallen believes there is little to no theoretical framework to explain undecided students' persistence. Also, students "have confused the construct of commitment to college completion with educational and career choice" (p. 103). Lewallen asserts that the majority of students are not sure of their major trajectory upon matriculation and "Being undecided is not the exception, but rather the norm" (p. 110). Furthermore, being undecided does not hurt students in the long run.

Part of the difficulty Lewallen finds in studying student pathways is that the reigning models of student progression such as Astin and Tinto, tend to view persistence as a relationship of fit of the student with the college environment. Lewallen's model demonstrates that only 24% of the variance in persistence was explained, meaning that "there is more unexplained about persistence than there is explained" (p. 109). Of course, Lewallen's results refute multiple classic theories (Abel 1966, Ashby 1966, Beal 1980, Foote 1980, TItley1980) that undecided students have a worse chance of persisting. The results here support Holland (1997) that "decided and undecided high school and college students are much more alike than different" (p. 404). Finally, Lewallen attacks many of the previous, classic studies for making statements about persistence differentials between decided and undecided students "with no reference to research that supports" (p.103) their claims and that "it is a quantum leap to infer that a student not decided about an academic major or career is not committed to college completion" (p.103).

> "Clearly, the time has come to recognize formally in our policies and practices that the majority of entering students are in an undecided mode. Being undecided is not the exception, but rather the norm" (p. 110).

2.2 Fundamental Underpinnings of Choice, Withdraw, and Switching

No treatment of major change would be complete without a discussion of major selection encompassing core theories from Tinto and Bean. Cabrera's 1992 study provides a great application of both Bean and Tinto's theories. Cabrera's study of 2453 first time in college (FTIC) freshmen of "traditional" age (under 24) consisted of a mixed methodology study of 79 items from various constructs (Bean, 1980; Metzner and Bean, 1987; Pascarella and Terenzini, 1980). Cabrera then proceeded to dissemble the differences between competing models of student persistence. Analogously, Volkwein notes the benefit of such a novel treatment in commitment studies in student persistence and attrition, as it predicts more than half of the persistence variation between the freshman and sophomore years (Volkwein and Lorang, 1996).

Tinto's theories, (Influenced by Durkheim's theory of suicide and Spady's works), dictate that goal commitment (graduation) and institutional commitment must align (Tinto, 1988). "All things being equal" between an individual's characteristics and those of the institution shape two commitments: a commitment to completing college or GOAL commitment; and a commitment to his/her institution (institutional commitment). Put simply, student attrition results from the interactions between a student and his or her educational environment. The main detractors from Tinto's work here are that external factors are not discussed, such as shaping/changing perceptions, commitments, and other student preferences.

Bean's model of student attrition is based on organizational turnover (Bean, 1990; Bean, 1980; Bean and Metzner, 1985). Beliefs in Bean's model shape attitudes and attitudes shape behavioral intentions. External factors are significant in Bean's model, and Bean noted that non-intellective factors played a major role in dropout decisions, including family approval, environmental factors, etc.

Bringing the two theories together, Cabrera concluded that Tinto's factors are more easily validated, but Bean's account for more variance in persistence and intent to persist (external factors) by a factor of two. Both models treat persistence as a complex, time-evolving process, and take into account that pre-college factors are important. Cabrera's work is similar to the work of Bean that demonstrated dropout rates were significantly affected by non-intellective factors (Bean, 1990).

Volkwein addresses these classic works through an introduction of "extenders" (Volkwein and Lorang, 1996). There are those students, dubbed "extenders," who prolong their stays in the academy for various reasons. Volkwein's study uses Cabrera's integrated model of student retention, surveying 428 students multiple times from 1991 through 1994. Interestingly enough, Tinto, Bean, Nora, and Cabrera did not address the concept of taking lighter credit loads to protect one's GPA. Volkwein's work concludes that for every semester below 15 credit hours a student takes, a student increases his chances of not graduating within four years by 3.2%. The effect of an entire point GPA increase increases the four year graduation probability by 5%.

Even with the strong potential for not graduating within four years, Volkwein's interviews uncover that "extenders" are overwhelming positive about their experience. Although nearly all students completed one or more semesters above fifteen credit hours, that did not outweigh the net contention of taking multiple semesters with fewer than fifteen credit hours. Of course, the effect of incoming credit hours from advanced placement examinations and elsewhere are critical, as well as attempting summer school credits, (more than 50% of the students in Volkwein's study did).

Pascarella's treatment of voluntary freshmen withdrawals shines further light on the subject (Pascarella and Terenzini, 1979). In a SUNY study of N=1457 with a follow up of N=773, Pascarella found that many good students leave of their own volition. Sometimes, the effect of a high GPA increases voluntary withdrawal since students leave for another institution. For men, Pascarella found a negative correlation between voluntary withdrawal and receiving help from faculty with a personal problem, and for women, the research demonstrated a negative correlation between voluntary withdrawal and obtaining information about courses and academic programs. These results show that positive personal interactions and information seeking attenuate the potential for voluntary freshmen withdrawal.

Another classic study of major switching is Pierson's study of Michigan State University students in 1958 using N=2369 graduates where N=734 switched majors at least once (Pierson, 1962). An interesting caveat of this study was the high percent of military veterans (~30%). While only two students changed majors in their senior year, 29% changed during their freshmen year, 45% changed during their sophomore year, and 26% changed during their junior year. Pierson noted that there was an observable pattern of transfer *away* from technical and scientific majors when switching. More than 60% of the students believed that they did not have enough information about their final major when they first matriculated, and of those students, about 50% of them believed that the curriculum for their first major was not what they had expected and 47% of them indicated that their future job prospects in their first major field did not appeal to them.

Addressing the high rate of attrition in engineering is certainly not a new phenomenon, and Apostal performed such a feat in 1968 (Apostal, 1968). Using the Strong Vocational Interest Blank to measure interests and Duncan's Multiple Range Test, Apostal studied 90 students at each engineering specialty at the University of Maine. While Apostal concludes that "it is well known that the interests of college students in engineering differ from the interests of non-engineering students" (p. 909), his main conclusion is that their interests tend to be stable over time.

Abel observed the effects of major changes in a liberal arts college sample of 89 students in 1966, all freshmen FTIC or transfers with first year status (Abel, 1966). The work revolves around attempting to decide what types of students should continue to progress within the engineering course of studies after having issues revolving around GPA. Abel's methodology is interesting and used a series of statements provided by students that were judged by an expert panel. The students had to write about their vocational and academic goals, and the expert panel had to judge the degree of "certainty" they possessed in such statements. Abel notes that low performing students who were certain differed subtly from those who were uncertain in terms of GPA, and thus could seem similar to a counselor. Since the expected correlation between a high correlation rate and low certainty did not exist, Abel strongly warns against the concept that simply choosing a major will yield a great GPA or lead to persistence or graduation.

Classical work on college drop outs such as Spady's and Bayer's define the college dropout in two ways: first, it includes anyone who leaves college at which he is registered; and second, it refers only to those who never receive a degree from any college (Bayer, 1968; Spady, 1970). Bayer demonstrated the gender divide among voluntary drop outs in his study, as men were more likely to voluntarily drop out and less likely than women to graduate within four years. "The corollary to this hypothesis is that men are less likely to be voluntary drop outs than are women" and "women who do graduate are more likely to finish on time" (p. 72). "Men in particular, however, appear to maintain high expectations despite the academic realities of college life" (p. 72).

> "There is also a growing body of data that suggests that the nature and strength of college goals and orientations are differentially linked to certain outcomes, depending on the sex of the student. It is fairly clear, for example, despite the recent upsurge of feminist rhetoric, that men face the necessity of establishing a position in the occupational structure on which their future income and status

will depend. For women, on the other hand, the decision to pursue a career is less often dictated by social or economic necessity. As a result, women are both freer to deal with college as an intrinsically rewarding experience and face less pressure to finish" (p. 72).

2.3 Alternative Metrics

Researchers such as Gillmore conclude that even though GPA increases the probability of graduating on time, the correct way to assert the effect of GPA on graduation is via graduation efficiency (Gillmore and Hoffman, 1997). The Graduation Efficiency Index (G.E.I.) is a cross-sectional metric constructed by Gillmore to probe the University of Washington bachelor degree recipients in 1993-1994. Part of the impetus for the G.E.I. is an increasing time to graduate. The Washington legislature believed that students taking longer than normal to graduate are using resources disproportionately. As an example, Gillmore cites that for the class that matriculated in 1991, only 36.7% of the students graduated on time.

A few of the conclusions Gillmore reaches are of note, such as degree programs that legitimately require more credits do not hurt efficiency, a benefit of the G.E.I. Also, transfer credit are properly handled within the G.E.I., as this metric does not benefit those with significant AP or transfer credits more so than those students who matriculated without them.

Of course, there are drawbacks to the G.E.I. For instance, it "assumes the number of credits required for a degree is appropriate," which given the politically charged nature of graduation metrics is a very dangerous assumption. Also, the "GEI is a measure that at this stage of development can be applied only to students who have obtained degrees." In other words, the students who do not obtain degrees drop out of the analysis altogether!

Lam uses the Bachelor Degree Progression Index (B.D.P.I.) to study N=18252 students among "three cohorts at a large public university during a ten year period who all graduated (Lam, 2007). Noting a strong contrast between the G.E.I. and the B.D.P.I., Lam notes that the G.E.I. is only from the point of view of the institution, and does not take into effect a student's point of view. The B.D.P.I. takes into account credits brought into the institution by the student upon matriculation. Noting that the traditional, four year model of graduation is too strict to use as a metric,

> "The once traditional two- to four-year college transfer has been supplemented by recognition of numerous other student paths—reverse transfer (four-year to two-year colleges), lateral transfer (two-year to two-year colleges or four-year to four-year colleges), concurrent enrollment in two institutions during the same term ("expediters" in Slark, 1982 and "double-dippers" by Gose, 1995), and multiple-transfer or swirling students (de los Santos and Wright, 1990) who may alternate enrollment in various colleges frequently by term. As noted by McCormick (2003), not all of these students exhibiting these various pathways are actually transfer students in the traditional sense. Some students simply supplement their home institution's offerings with convenient offerings from other institutions" (p. 8).

Testifying to the power of the B.D.P.I. to describe student progression, while engineering students had a very high number of credits upon graduation, their extremely low B.D.P.I. relative to other majors indicates that engineering students have a high chance to bring credits from other institutions whereas other majors do not. Also, the B.D.P.I. reveals a gender gap where G.E.I. does not, for instance, in the physical sciences, the B.D.P.I. was 89.2% for men and 67.8% for women, whereas the G.E.I.s for physical sciences are relatively similar between the sexes.

The retention rates of part-time students is of concern to engineering colleges. Godfrey's study of two Australian engineering institutions cited a lower rate of retention among part time students (62-72% instead of 75-94%) (Godfrey et al., 2010). Godfrey uses the "admissions index," or the matriculation ranking of students, a commonplace metric Australian higher education. Compared with the US and the MIDFIELD database, the Australian study by Godfrey is radically different in that "the number of students switching to a non-engineering degree from the cohorts entering above first year level were so small (<1%) in both institutions that they have not been included" (p. F3E-3). In the United States in general and in the MIDFIELD study, the lower number of students switching out of engineering to non-engineering degree programs after the first year is much higher than 1%. Of course, two problems with this paper are that it does not look at who switched from engineering to non-engineering in any detail, and loses track of all students once they leave engineering itself.

Another study from Australia studies the Student Progress Rate (S.P.R.) metric from three cohorts in 2003 through 2005 with N of 4405, 4414, and 3684 (Zhongjun and Roger, 2006). Once again, the attrition rate differential among part time students versus full time students is expansive. Cao states that an attrition rate that is three times higher for part time than full time is “unacceptable.” and “A low level of academic achievement in the commencing year was the most powerful predictor of student attrition in this study” (p. 13).

The S.P.R. can be defined as, “The domestic commencing bachelors student attrition rate was calculated, using methods based on the DEST definition (DEST, 2004). This rate refers to the proportion of domestic students (expressed as a percentage) who commenced a bachelor level course at the institution who neither re-enrolled nor graduated in the year following their commencing year. As a measure of academic progress, the student progress rate was also calculated, using the DEST definition. It was calculated as the proportion of assessed load (measured in EFTSU/EFTSL and expressed as a percentage) passed by a student in their commencing year” (p.13).

2.4 Major Changing as a Path or Curricular Treatment

Two prevailing paradigms permeate the discussion of the student pathway from a quantitative viewpoint: the first being the pathway treatment in and out of a major or set of majors; and second, the flexibility or leeway within an individual major set and how such slack or lack thereof engenders a more or less favorable situation for the student and/or groups of students. The traditional nature of the pathway into and out of engineering majors has been reflected upon quantitatively in MIDFIELD papers and elsewhere (Adelman, 1998; Atman et al., 2009; Ohland et al., 2008), but still is plagued by statements such as, “There are not that many pathways into ENGR” (Atman et al.,

2009) (p. 23). Such statements skirt over the issues involving major changes and directions that take place within engineering itself, which may or may not be as robust, complex, and frequent for students in any other circumstance.

Departing the cross sectional approach to most student centered data sets so often lamented by others in the field (Astin and Lee, 2003), Robinson's proposal of a new type of pathway metric and subsequent theoretical treatise outlines the case for more robust metrics at the college level (Robinson, 2004; Robinson and Bornholt, 2007). The main impetus behind such a metric is renewed focus on "identifying and representing pathways of student progression through a degree course" (2004, p. 1). A brief primer of Robinson's metric is the following: all students have codes for progression, such that one code defines large-scale pathways; the codes are simplified so that a "1" indicates matriculation status, "2" means a progression from one year or semester or unit of enrollment to the next without a change in academic status or failure of a course or group of required courses, etc; "3" meaning a repeat of a unit; "5" being a transfer of major; and as an example, a "12222" would mean a student matriculated under normal circumstances, and progressed through each of four units of enrollment time (in this case years) without any issues.

While standard metrics of degree completion abound, they do not take into account the totality of a student's career, or as Robinson says, "cohort-based statistics or cross-sectional census-like counts" (p. 2). Alternative such as the student progress ratio are simply incomplete (Dobson et al., 1997). They are not suitable for tracking a student's progression through a degree program for the entirety of his or her career.

The majority of students within the study followed a straight path (58.3%), although the overall number of students studied (N=72 starting in the first year) leaves substantial room for larger, longitudinal expansion of the metric (p.8). Taking into account the issues surrounding a low N, the model outlined by Robinson indeed notes that a high percentage of students in the study simply pass through the four years of curriculum in a normative fashion, while 11.1% who progressed failed one course at some point within a five-year graduation baseline (p. 9).

Recent work on discontinuities evokes Robinson's work on pathways to a different degree. Ewert's work focuses primarily on the academic outcome differences between the sexes when confronted with longitudinally trackable shifts in enrollment and status, for instance, a shift from full time to part time status and then back again (Ewert, 2010). Ewert's work studies the concept of "disrupted pathways" in the college experience, and is a novel methodology, whereby students who have discontinuities in their studies are probed and then divided by gender. In his own words, "Since students who follow disrupted pathways are less likely to persist to college graduation" (p. 747).

While not immediately apparent, the notion of multiple disruptions or "discontinuities" to the academic pathway discussed in Ewert's work actually encompasses the student who has shifted majors. Something that is interesting is that within the work of Robinson and Ewert and others, the idea of a change of course or path of study seems to be viewed as a discontinuity on a more deleterious scale than in the American system. The idea of a change of major being a "discontinuity" certainly is not a description I have read elsewhere in the sparse literature on major changing. Even within the community of researchers discussing engineering undecided students and their pathways, the notion of an undecided student being worse off than a part-time one, or being described in a fashion that would indicate a change of major extricates the student from the traditional, healthy progression toward a university degree, seems a bit extreme.

Perhaps the main fault of Ewert's work, is that even with a substantial sample size (N=4640), is the over classification of student variables. A uniquely powerful result from EWERT's work would be simply in the discussion, as this paper endeavors, of the penalty for unique instances of disruption or discontinuance. While the variance discussion does indeed show the variance in outcomes presented by individual factors, a simpler visual map of the penalty to the outcomes of graduation time and semesters enrolled caused by individual disruptions would be powerful and simple.

The study itself relied on incomplete survey data that was not at the institutional level. In other words, the researchers are simply not seeing what the institution sees.

While the qualitative value of such an analysis is indispensable, it is inherently incomplete and when constructing an analysis from the top down, it is imperative one possesses the institution's view to truly model differences between institutional effects (Ewert, 2010). Also, no evidence that men's enrollment in more selective schools accounts for the difference between sexes in pathways. Furthermore, the conclusion of selection differences is obfuscated by a strong differential between the sexes in terms of multiple disruptions, most prominently observed by Ewert in Asian, Black, and White populations.

Analogous to Ewert and Robin’s work, Goldrick-Rab observed that the concentration of pathways among particular groups of students, whether divided along racial, ethnic, social, or otherwise, has long-lasting and negative effects for an institution (Goldrick-Rab, 2006). One way of elaborating upon this phenomenon from Goldrick-Rab’s work is that when a less-than-desirable pathway becomes convergent for any group of students, the existence of the pathway indicates a “stratification” (p.73). Another way of explaining Goldrick-Rab’s viewpoint lies in the treatment of a pathway as a disruption or discontinuity in a student group’s pathway, especially with reference to a pathway defined by a particular SES domain. Examples of these disruptions include a transfer from one major to another, enrolling part time or having a part-time pathway, and a period of non-enrollment for six months or longer (outside of the summer session).

As Willcoxson notes the subtle and more overarching differences from semester to semester of students’ needs, so too does a semesters completion metric help compliment such observations (Willcoxson, 2010). Flexibility in early course completion can speak to Willcoxson’s needfinding of the undergraduate population. This may support Willcoxson’s work in that student attrition is associated with an increasingly narrow range of factors as time progresses. Flexibility can be expanded or attenuated in congruence or contra outside impetuses in a student’s life, such as personal issues, career direction, self-efficacy, and other competing factors. My research paired with a qualitative study of MIDFIELD schools may reveal, for instance, that student flexibility in course completion is inversely proportional to a preponderance of distracting outside forces. I may also uncover that students find more ways to exploit a system's inherent flexibility when they are dealing with other issues, allowing them to make the system work with them in order to succeed.

Szafran wished to study the effect of course "difficulty" on student success in a study of N=487 freshmen in a 1996 cohort at Stephen Austin State University (Szafran, 2001). Using a survey ad accounting for on campus working hours, they concluded that course difficulty had a direct effect on student retention, but more importantly, concluded that the standard advice given to student to take easier, first semester course loads may not be the best one (K, 1994). This definition of "difficulty" is severely limited, but may be the best that a purely longitudinal study can afford at the current time, given that the researchers found only two previous studies of course difficulty (Bean and Bradley, 1986; Pike, 1991).

Stevens' ethnographic observations yielded some interesting conclusions that speak to curriculum reform (Stevens, 2007). As a whole, he concludes, somewhat shockingly that "engineering education does an insufficient job in giving students the experience of engineering as a meaningful craft, or that as engineers they will be able to contribute to a better world" (p. 2). Of course, anecdotally, many researchers within the discipline have probably felt what Stevens concludes.

His two "solutions" for engineering education includes: first, inject "real" engineering experiences into the major pathway; and second, weed out as much of the curriculum as possible. While some departments may be highly reluctant to cut courses, Stevens contends that such a pairing down of required courses would help departments refocus on engineering fundamentals. Given the observations by Stevens that students in engineering are already consumed by the future lifestyle an engineering degree can afford and that the engineering bent as undergraduates already dominates their lives, any movement of departments towards a more hands-on or "real" engineering approach at the undergraduate level will be welcomed by the students.

In Stevens' four-year study he coins the term *navigational flexibility (Stevens et al., 2008)* (p.361). Navigational flexibility is a term used to describe the differences between students in relationship to how they traverse the curriculum. Stevens states that students travel along "official" and "unofficial" routes in the engineering curriculum. Of course, "official" routes usually have well documented pathways and transparent histories concerning the policies that brought them into being. The "unofficial" routes can have a variety of ways they are documented and revealed to students. For instance, various students groups keep information on exceptions to rules or ways to go about formal strategies. Fraternities are the standard example of large groups that have access to study materials and advice on negotiating a major's pathway.

Pertinent to this paper's research are the observations by Stevens of the early versus later engineering courses and the divide that separates them. He even notes the stark divide between the first two and last two years of engineering coursework or specialization work. Stevens concludes that the early courses in engineering are permeated by structured problems, an observation noted by Felder and many others within the field. Stevens also states that later courses tend to include more open-ended problems, with a more hands off approach by the professors. The strange duplicity here is that if later course are more open in their nature, then why would the engineering curriculum seem so exclusive and difficult concerning required courses? A student cannot simply enroll in an upper-level engineering courses without a myriad of required, background courses – at least not on paper and from what many engineering colleges' official pathways would lead a student to believe. Determining a novel way to objectively determine how flexible the engineering curriculum is throughout the years is a major goal of this research.

One of the major problems with the pipeline metaphor within engineering education according to Stevens is figuring out how to recover those trapped within it. The major issue with the pipeline from my research's vantage point is the metaphor itself. If the students who succeed within engineering all take a standard, "point A to point B" path through engineering, then the pipeline metaphor is accurate; however, if students who succeed within engineering take a route that starts at point A, retracts to point Z, works on points C and D at the same time while hoping to move to B and then F, then the pipeline becomes more of a recursive web of mimicry than a pipeline. The flexibility demonstrated by students in how they make or discover exceptions to the rules may define just what is really going on in their progression. I am willing to believe that their pathways are anything but normal, but that they are interesting with turns and false starts and all sorts of interesting routes.

Hulst's study of N=1578 students in twelve engineering schools in the Netherlands probes the effect of curriculum organization upon students (van der Hulst and Jansen, 2002). Hulst asserts three categories of effects dominate curricular organization: first, the distribution of activities during the year; second, instructional characteristics; and third, examination characteristics. The primary assertion of Hulst's work is that *where* a student devotes time to study is affected by the organization of the curriculum. Of course, this organization in Hulst's work not only means when a course is taken, but the number of examinations, required coursework, number of courses taken in parallel, and etc. Hulst discovered that lower number of parallel courses, a low student age, a lower number of final student examinations, the number of preparation weeks, and simply being female all led to greater degree progress. What Hulst also uncovered is that the preponderance of theoretical courses in a student's schedule will lead to fewer courses taken in general. The most important conclusion, however, is that the variance in the number of credit hours earned by a student is not dictated by any curriculum organization effects Hulst studied in his null effects model. The net contention of Hulst's work on curricular organization is that while gender, age, secondary (high school) success, and other factors can contributed significantly to outcomes, the current paradigm of taking a static approach to curricular organization's effect on outcomes may not explain the variance in outcomes such as successfully completed courses.

My work offers a novel metric that approaches this conundrum. Part of the power of a curricular completion metric is that the metric itself is time invariant and policy-determined. Its inherent nature is to demonstrate how students negotiate the strictly defined graduate parameters of a four year institution. If constructs such as curricular organization in Hulst's null effects model cannot explain outcome variance to a greater degree than basic demographics, perhaps it is because the curricular organizational parameters are too restrictive.

Trow outlines the expediency with which the educational system must work on curricular reform, and also notes some of the pitfalls of massive curricular change over the years (Trow, 1973). The pressures exerted upon the education system by political agencies, a styming of diversity-engendering factors, and the seemingly inherent standardization inflicted upon education by outside forces all have to be considered in order for curricular revamping to occur. For instance, simply enrolling a greater and greater percentage of the masses in the collegiate system greatly changes the courses offered and the degree pathways available en masse, and "Only in the United States does this sort of massive college enrollment take place" (p. 7).

> "The forces working against genuine diversity in higher education in most European countries are rather stronger than those working to sustain or increase it" (p. 54).

While Trow notes that the egalitarian aspects of universal access to education change the structure of the curriculum itself, the degree to which that curriculum is changed is not references or tested within his seminal work. Establishing a curricular sets metric for large institutions allows them to compare their own institution to some of the lofty declarations made by Trow and his colleagues. For instance, an institution could see if its largeness is somehow impeding student flexibility or encouraging it. Also, studying curricular flexibility can address the rate of change of flexibility within an institution relative to policy and structural changes. If students demonstrate great flexibility when seemingly draconian or myopic curricular reforms are implemented, then an institution could declare that flexibility is endemic to its culture and future curricular reforms could show greater sensitivity and reverence for such flexibility.

Atman's work cites numerous curricular concerns, probably most importantly, that of gaming the system versus legitimizing the curriculum (Atman et al., 2009). For instance, curriculum overload (p. 5) and engineers being more likely to stick with their majors (p. 9). That being said, Atman's assertion that "there are not that many pathways into engineering" (p. 23) may run contra to the curricular flexibility students enjoy within engineering disciplines. In fact, the weaknesses in fundamental concepts noted by Harrison, Streveler and their colleagues may be explained by how students navigate the curriculum itself. With students juggling courses and navigating an officially recalcitrant curriculum, they devote more energy to simply completing curriculum more so than mastering core concepts. The best way to "waste" time, then, may be to navigate the curriculum and take advantage of the system in order to find the easiest way through instead of mastering the curriculum. This may explain part of the effect Harrison and Streveler noticed; there is a deep seated problem within engineering that fundamental concepts are not grasped by advanced students (Harrison et al., 2006). Also, while Atman notes differences between men and women, perhaps curricular flexibility sheds light on these differences.

Godfrey's case for curriculum reform stems from a case study of 1344 students and nearly one hundred faculty (Godfrey and Parker, 2010). Of particular note are Godfrey's assertions of the situationalized nature of the engineering craft itself. This work is summarized as the shift from the "right" answer to paradigm to the "best" answer one. Engineering, as it acts as a college, tends to behave as its own institution, a phenomenon that individual departments within engineering also tend to mimic. In this critical nexus points identified as the *relationship to environment*, it appears to Godfrey that engineering has a vast expanse to traverse when negotiating curricular changes. For instance, if the faculty believes that the curriculum should be shaped solely by the discipline, then why should engineering colleges even be situated within the larger context of a university? Surely there must be other concerns to the engineering faculty concerning reforming curriculum than to emulate disciplinary issues. The possibility does exist that engineering faculty are so steeped within their particular fields that the only reforms they can imagine are myopic, or perhaps the only *possible* or *effective* reforms are myopic.

Beggs' paper of student major choice running congruent to their interests speaks to the importance of the curriculum (Beggs et al., 2008). Perhaps most importantly, Beggs concludes that an internal realignment of the curriculum of the major coursework with what is communicated to students is *not* necessary, despite a culture among students to employ "strategies of indecision" (p. 382) instead of logic when choosing a major. Further recommendations by Beggs speak to curricular arrangement, including delaying the choice of a major, which can have devastating effects on the timing of completing required coursework in a standard, four year degree pathway. Also, to *consider the uniqueness* of an institution, having information about how students progress through a curriculum may be one fundamental stepping stone in that process.

Porter's use of the Beginning Postsecondary Student (BPS) surveys along with IPEDS led to a few conclusions on curriculum (Porter, 2006). For instance, Porter noted that larger schools tended to have more courses (p. 529), but did not extrapolate a relationship between the number of courses and the possibly number of pathways within a major or a major's flexibility. Porter notes that the peer effect as detailed by Astin has a much greater effect on student outcomes than how rich or poor a school is.

Suresh's conjecture that the key to persistence is overcoming the starting block of *barrier* courses (Suresh, 2007). Being able to study the pathways of these students regardless of what courses they failed but simply in regards to when within the curriculum they struggled presents a new methodology for exploring the three categories. In fact, arranging the required engineering curriculum into sets based on the rules of the institution itself shows respect for the institution's own policies.

Gross's survey of N=189 students at SUNY probed how engineering students self-select and reinforce engineering stereotypes (Gross and Gaier, 1974). What Gross did not find was whether or not the engineering curriculum served as a mechanism for such behaviors, as other majors appears to do the same. In fact, what Gross discovered is that students who were most decided upon their career trajectory self-stereotyped more than those who did not. “The most crucial factor affecting applicability here appears to be the degree of decidedness a student has regarding his vocational choice. Those most certain of their occupational choice seem more likely to fit Holland's model” (p. 212).

Molnar’s study debates the notion of curricular mobility from the vantage point of struggling students who may or may not transfer from engineering to a less technical discipline. Molnar conjectures that the lower rigor involved in a non-engineering curriculum may lure students on the precipice of attrition into outside majors. In other words, the concept of engineering being difficult while other majors are easy is a myth that simply will not die. Conversely, it’s possible that withdraws, given their overall engineering interest and negative industrial management interest, “may attempt to persevere in an engineering curriculum despite the indication of possible university termination as evidenced by their initial performance in engineering” (p. 56).

Pike’s work is centered around institutional organization, a key component of curricular discussions (Pike, 2003). In a study of N=1500 students from around the nation. Pike makes the argument that “no meaningful differences were found in students’ perceptions of the college environment, levels of academic and social involvement, integration of information, or educational outcomes by Carnegie classification” (p. 241), and that “broad institutional effects on student experiences and self-reported learning gains appear to be minimal” (p. 259).

Felder’s paper makes a call for the overthrowing of a sequential methodology in engineering education (Felder and Silverman, 1988). For instance, Felder states that the presentation of certain engineering phenomena within courses tends to obfuscate the actual inner workings of the craft, misleading students as to how the discipline truly functions and thus stifling their development. Another way of putting that is the deductive teaching methodology lulls students into a false sense of order. “When students see a perfectly ordered and concise exposition of a relatively complex derivation they tend to think that the author/instructor originally came up with the material in the same neat fashion, which they (the students) could never have done.

They may then conclude that the course and perhaps the curriculum and the profession are beyond their abilities" (p. 678).

Titley noted in his seminal 1976 work and Osipow in his 1973 paper both indicate that students even of the outstanding bent encounter difficulty with navigating and succeeding within the required curriculum in their majors (Osipow and Fitzgerald, 1995; Titley et al., 1976). Such struggling within a major can appear to the casual observer to be similar to what students with achievement problems look like. If students with low GPAs and SAT scores have similar patterns of flexibility within a curriculum, that certainly is generative of future research, as it indicates that flexibility is dichotomous: first, it is a privilege of the highly motivated and resourceful; and second, it is the saving grace of those students for whom the curriculum may be arduous.

Danielak's study of one student makes a call for a shift in the engineering paradigm to reward and encourage students who believe that learning is their hobby and through incorporating "sense" making (Danielak et al., 2010). Such a change in the curriculum may prove useful as today's economy values skills and those who show intellectual interest in their work. As noting about a successful student, his learning views "contribute to a growing sense of contrast between how he thinks engineering courses should be taught and assessed and his experiences of how they are taught and assessed" (p.1). Also, engineering "doesn't reward good learning so much as it rewards regurgitation and good memory" (p. 3).

2.5 Major Decisions as a Chance Impetus or Message Framing

Although novel, anecdotal evidence from the authors has demonstrated that a good deal of a student's major choice may be due to factors completely outside of his or her control. Bright's work expands upon the notion of such "change" impetuses for career decisions (Bright et al., 2005). Bright noticed in a series of 772 interviews that students described "chance" events affecting major career decisions at a rate of nearly 70%, while only 10% of students did not believe chance affected their career decisions. Bright's work expands upon the foundational work of Roe in occupational studies (Roe and Baruch, 1967). Roe's research discovered that students' descriptions of their career pathways did not seem to follow a succession of defined or logical choices. Instead, students tended to describe events shaping their future as being pivotal to their choices.

Even the types of advice students receive on majors or message framing affects a students' choice of major. Tansley's study demonstrated that the way an adviser frames the consequences of various actions or inactions either engendered or prevented positive student action concerning their majors (Tansley et al., 2007). Tansley noted that "loss framed" messages promoted students to engage in more career related behaviors. In other words, providing students with advice such as "If you're lazy, you'll fail," increases student engagement with positive career related behaviors as opposed to telling them, "If you work hard, you'll do well."

2.6 The Reasoning of a Change of Degree

The overall problem of when to choose a major is complicated by the deeper and longer lasting effects of changing a student's perception of the purpose of a college education. Kimweli in a study of 321 students in multiple universities noticed that students who choose majors earlier in their careers held a lower appreciation of art compared to those who took more time in finding their final major (Kimweli, 1999). Also, while older students tend to be more appreciative of art in general, the simple act of picking a final major sooner in one's career led to a lower appreciate of pursuits related to less technical university studies. The student interviews reflected that exposure to art led to an improved overall quality of life. Conversely, as students age, their desire to major in engineering wanes, and they need special encouragement to pursue a degree in engineering and the more technical majors.

Analogous to Kimweli's work, Leppel noticed in a study using beginning postsecondary students in 1990 that older students also needed a push to major in engineering as age alone is a deterring factor from pursuing engineering (Leppel, 2001). Leppel's work notes differences in that types of majors students matriculated into based on the profession of their parents. Males with executives and professionals for mothers were more like to enter into education or humanities or social science majors, whereas females with the same types of mothers were more likely to choose science or engineering or health science major fields. If both parents hail from executive or professional backgrounds, males tend to enter into the humanities or social sciences, whereas women tend to enter science or engineering or health sciences. Leppel asserts that although there anecdotally seems to be a difference in the influence factors of mothers and fathers, that the influence of a student's mother on major choice is not stronger than the father's. Finally and a seeming conundrum, SES is discovered to not have a strong effect on major choice for men and women, but at the higher ends of the SES spectrum, males tend to pursue business majors whereas women are not as likely to pursue a business related major.

2.7 Sex Segregation

Frehill constructed a multinomial logit model with a logit function for dichotomous outcomes using 1980 and 1982 surveys from the High School sand Beyond study (Frehill, 1997). His work speaks to the "gap" of women in STEM in multiple ways. First, women were not prevented by family orientation values from entering into engineering, thus addressing the highly sexist charged notion that women want to have families or have family orientations that prevent them from succeeding in engineering. Also, Frehill believes that presenting a positive image of engineering to young women is a great intervention technique to bolster the ranks of females within engineering. For instance, "If nothing changed except that men moved to women's means on high school preparation and gendered work attitudes, then 4.1% fewer males would choose engineering, closing the overall sex gap by 32.6%" (p.242).

2.8 Summary

Allow me to reiterate that the three-fold paradigm I contemplated when first embarking upon this journey consisted of:

1. Course major changes.
2. Semester enrollment patterns
3. Course level analysis of a small segment of required courses

When perusing what could be done over the period of a year, I noticed that basic questions had to be addressed, questions that reached beyond the scope of a cross sectional data treatment. The first question came from a 2010 paper in ASEE that probed the overall enrollment time of students with respect to the number of major changes they made. I had noticed that the increase in time to degree (measured in terms enrolled) appeared to increase in a regular, linear fashion with respect to the number of major changes recorded by the registrars at MIDFIELD participating institutions. Also, the patterns for those enrolled in FYE seemed a bit different. It seems that they took fewer enrolled semesters to graduate, on average. I wanted to know if this pattern of increased time to graduation held for other large segments of the database. Did the pattern of students taking more time to graduate hold equally well for the non-engineering students as the engineers? Did students who matriculate into engineering after having enrolled in the liberal arts have some sort of inherent disadvantage? All of those questions and more were contained by the major change problem at first.

Second, years later I noticed even stranger behavior in the database. I noticed that not only did students take more time to graduate per major change, they took longer to drop out per major change. Now, on its surface, this problem seems to be quite analogous to the first and not really a novel phenomenon; however, when contemplating that some majors or pathways pride themselves on helping place students into the correct discipline *perhaps there could be a set of majors or a set of enrollment statistics that traps students, outside of the academy? Could there be a problem with FYE programs that causes their students to stay in school for more terms* *even after they leave? If a student is going to drop out anyway, wouldn't it be best for him to drop out early?* These sorts of questions are the questions that guided the second half of the major change research in this thesis.

All the while I pondered major changes, I had a paper in 2011 at ASEE that delved into a novel methodology for calculating semester "sets" of completed coursework. Not only was the resolution of the MIDFIELD data beyond anything previously published, but the construct used was radically different. I wanted to know if *flexibility* within engineering majors could be measured and what results would be demonstrated. *Do students who benefit from extra flexibility in the curriculum fair better or worse than those who are more normative?* In other words, do those students who fly through the curriculum by taking every course have a better chance of graduating early than those who do not? While probing these questions visually and philosophically, I added to these questions. I wanted to know *if students who exercised more flexibility switched majors more often than those who did not?* As it turns out, there is an interesting pattern between the pattern of major change, curricular set completion, and time to graduation measured in overall terms enrolled. While the results presented within this thesis is a novel treatment, they are by no means the end of this conversation, and updated revisions of these problem will certainly reveal more interesting phenomena, especially with the additional MIDFIELD schools.

CHAPTER 3. METHODS

3.1 Data Populations

The MIDFIELD database contains records for more than one million first-time-in-college (FTIC) students matriculating in any major at participating institutions (Long, 2008; Ohland et al., 2008). The studies here used three subsets of the MIDFIELD database: the major change section used a segment consisting of ten MIDFIELD schools with 871,742 total students. The curricular sets used a segment consisting of eleven schools further delimited by using FTIC students with engineering experience and where I was able to construct a curricular set, which narrowed the segment down to 165,116 students. The sections analysis for three core courses used a subset of the data from nine of the partner MIDFIELD institutions that provided data on individual sections allowing the constructions of a hierarchical linear model. I tallied all of the instances when students enrolled in a first semester/quarter, core chemistry, calculus, or physics class required for engineering majors that contained section data. I further pared down this population by removing students who repeated a course and received zero credits as per institution policy and cleaning up any remaining, erroneous section and grade data. The net contention of these routines yielded a data set of 161,456 instances of student who ever declared an engineering major and their grades within three core course sections.

The MIDFIELD schools are all public institutions and are mostly located in the southeastern United States, yet their size and diversity help make the results generalizable. These partner institutions have larger overall enrollment and engineering programs than average compared to the more than 300 colleges with engineering programs. The partners include six of the fifty largest U.S. engineering programs in terms of undergraduate enrollment, resulting in a population that includes more than 1/10 of all engineering graduates of U.S. engineering programs. MIDFIELD's female population comprises 22.1 percent of students, which aligns with national averages of 20 percent from 1999-2003 (Cosentino de Cohen and Deterding, 2009) and 22 percent in 2005 (National Science Board, 2008).

3.2 What Counts as a Major Change?

Given the review of some relevant papers in Table 1, it would behoove us to emphasize the fact that while there are theories that group majors in order to better accommodate policy issues endemic to an institution (Theophilides et al., 1984), a smaller data sample (Titley et al., 1976), or to address inequities in certain fields (George-Jackson, 2011), the vast majority of papers involving major switching or major declaration trust the host institution's registrar as to what is a major choice, when the major choice was made, and when the switch between majors occurs. The attitude of trusting the host institution's registrar is a longstanding tradition within the MIDFIELD group (Ohland et al., 2008).

Two strong decisions within all analyses performed were: first, the decision to generally not count the switch in and out of first year engineering (FYE) as an explicit change; and second, not attempting to account for concurrent classes (aka rectifying for the problem of coursework latency). There are numerous arguments for and against counting first year engineering explicitly as a major change. Here are some of the arguments for and against FYE being counted:

3.1.1 Against Counting FYE

1. FYE is a "holding bin" aka a temporary space for students. Students always intend to leave FYE and go somewhere else in their academic careers.
2. Students cannot and should not be held accountable for special programs dictate by policy at their home institution.
3. FYE is not a degree-granting program. One cannot simply graduate in FYE.
4. FYE is impossible to "come back to" after leaving aka one cannot transfer in and out of FYE.

5. A “directed” pathway major, aka, FYE indicates that students will move on to an engineering-related major. It is more indicative of a major-related pathway than undecided.

3.1.2 For Counting FYE

1. Most analyses of student progression defer to the registrar of the home institution as the final arbitrator of these issues. In the MIDFIELD group we say “we trust the institutions.”
2. Students can and should be held accountable for administrative policy decisions at their institution of choice. Just because “all” or “some” or “no” institutions have a certain policy doesn’t mean I shouldn’t take into account that policy’s effect on a student’s progression. Too do anything less is to not trust the home institution.
3. FYE still is a place students exist, so whether or not it is a holding bin is irrelevant. Not taking into account its effect shows great disrespect for its importance in a student’s career.
4. Undecided is not a degree-granting program yet moving in and out of undecided is a major choice.
5. Switching from undecided to anything else is a major change, so FYE should be, too. One cannot simply graduate in undecided.
6. Students can switch into and out of FYE programs just like they would undecided.

A third and more subtle decision made within major selection is the nature of the undecided student him or herself. While the literature presented here certainly has a bit to say about the undecided student, the history of the treatment of such students is poor by the literature’s one statements. I shall touch upon this problem more in the discussion section; however, it must be stated that all undecided categories are treated as any other major declaration when switching in or out of them.

3.2 The Nature of Curricular Sets

The "curricular sets" constructed in this paper were constructed using the individual student data available in the database. Student electronic transcripts were compared to the required engineering curricula by major, semester and matriculation catalog year for every institution. If a student, at some point in the academic career, completed the required curriculum for a semester, then credit was given for completing that semester's required curriculum, thus a "Y" for a given semester's work means that a student had completed all of the required courses for graduation at any time during the student's career. In order to visually arrange the student curricular completion "pathway," the semesters are always ordered sequentially, so "YYYN" means a student successfully completed all of the courses in the first, three semesters of his/her major, and did not complete all of the courses in the last semester of his/her major.

The advantages of such a curricular set metric are expansive. First, such a metric is easily interpreted by both modeling packages and visualization routines. Dichotomous or binary systems have been well studied and lend themselves to complex analysis. Second, such a metric makes inherently more sense to when presented. Most individuals can understand what a simple "yes" or "no" for "completing an entire curricular set" means. That is the only thing a person looking at such a curricular sets graph needs to understand. Third, being that I have delimited to students who have graduated, I do not need to incorporate other means of identifying those who leave the system with anything other than a yes or a no. Fourth, this system is primarily time-invariant. The order in which the courses were taken do not matter, what matters is only what did or did not happen on the completion end of things for the students throughout their careers. This greatly simplifies things from the end-user point of view. Imagine an administrator who wants a large-scale picture of how curricular changes are being traversed by students – this type of analysis yields a powerful tool for such an individual without other caveats. Fifth and probably most importantly, such an analysis leaves out significant identifiable data about the institution; therefor, participating institutions can use such charts to analyze their curricular sets without worrying about them causing harm to an institutions reputation. The only real damage that could be done to a university of college or major program that uses such a chart would be that too many of their graduates are exercising "flexibility" as they progress along their studies. Such a chart does not point the finger at any one particular institution within a university; it merely notes the prevalence of complete coursework along a particular major pathway.

It is important to carefully describe exactly what such a methodology includes and what it leaves behind. First, the "semester" in this method is comprised of the recommended sets of courses that are outlined by a student's major, and when they are taken does not matter. In this study, a student could take all of the "first semester" courses ten years after matriculating to a university, and the student would have a "Y" in the database to mark he/she completed the first semester's coursework. Second, the database is limited to all of the data provided by the institutions. Summer courses taken at universities other than a student's home institution and AP course credits do not appear on their records. Third, exceptions to the rules made internally are not part of the MIDFIELD database. An example of an "exception" would be students whose departments regularly allow them to waive a perquisite course upon completion of more advanced one. Such exceptions are largely ignored by the engineering education community.

The testing for this methodology was performed by my research colleague and MIDFIELD data steward, Russell Long. He tested the code multiple times against manual searches of students' required course sets from major requirement tables on file at every MIDFIELD institutions. Also, I took one hundred civil engineering students at random from one of the schools for a given set of years and manually checked that they had a missing required course when labeled as an "N" for a given semester. The most seemingly daunting problem of dealing with the issue of elective courses was dealt with by: leaving out the eighth semester of the curriculum in all of my binary tree constructions; and, second, not counting electives.

This “binary tree” methodology lends itself to be a novel metric to the field of engineering education, and one previously unexplored in the field of student assessment. Other advantages of a curricular set metric include: the mathematical principles underlying such a method are accessible, making more advanced, quantitative analysis possible(Kupek, 2006); and there are multiple ways of visualizing such data that allow for exploration of significant patterns and presentation to a general audience. (Frees, 2004)

CHAPTER 4. RESULTS

4.1 Description of Graphs

The scale of each graph was chosen to emphasize the large scale problems needing to be addressed within educational studies and within engineering education. Each graph follows a particular group of students, with a caveat to each. For instance, Figure 2 looks only at students whose matriculate in (or first select an) engineering major as the only selection factor. Figure 3 looks at only students who graduated in an engineering major. The purpose of these large scale selection parameters is to look at the bigger picture of groups of students and see if there is some difference between them.

4.2 Findings

4.2.1 Finding One: In the Aggregate, Switching Majors Does Not Prevent Graduation

There simply is no evidence from my treatment of hundreds of thousands of students in the first seven graphs that students with a higher number of major changes are more likely to leave school without graduating. If anything, the data shows that students who switch majors are more likely to succeed when aggregated over time and over any number of majors in all MIDFIELD schools. That is, if a student has both the ability and the motivation to switch, he or she may have some empirical data that switching is in his or her best interest. The increase in graduation rate with the number of major changes shown Figure 1 is evidence of this.

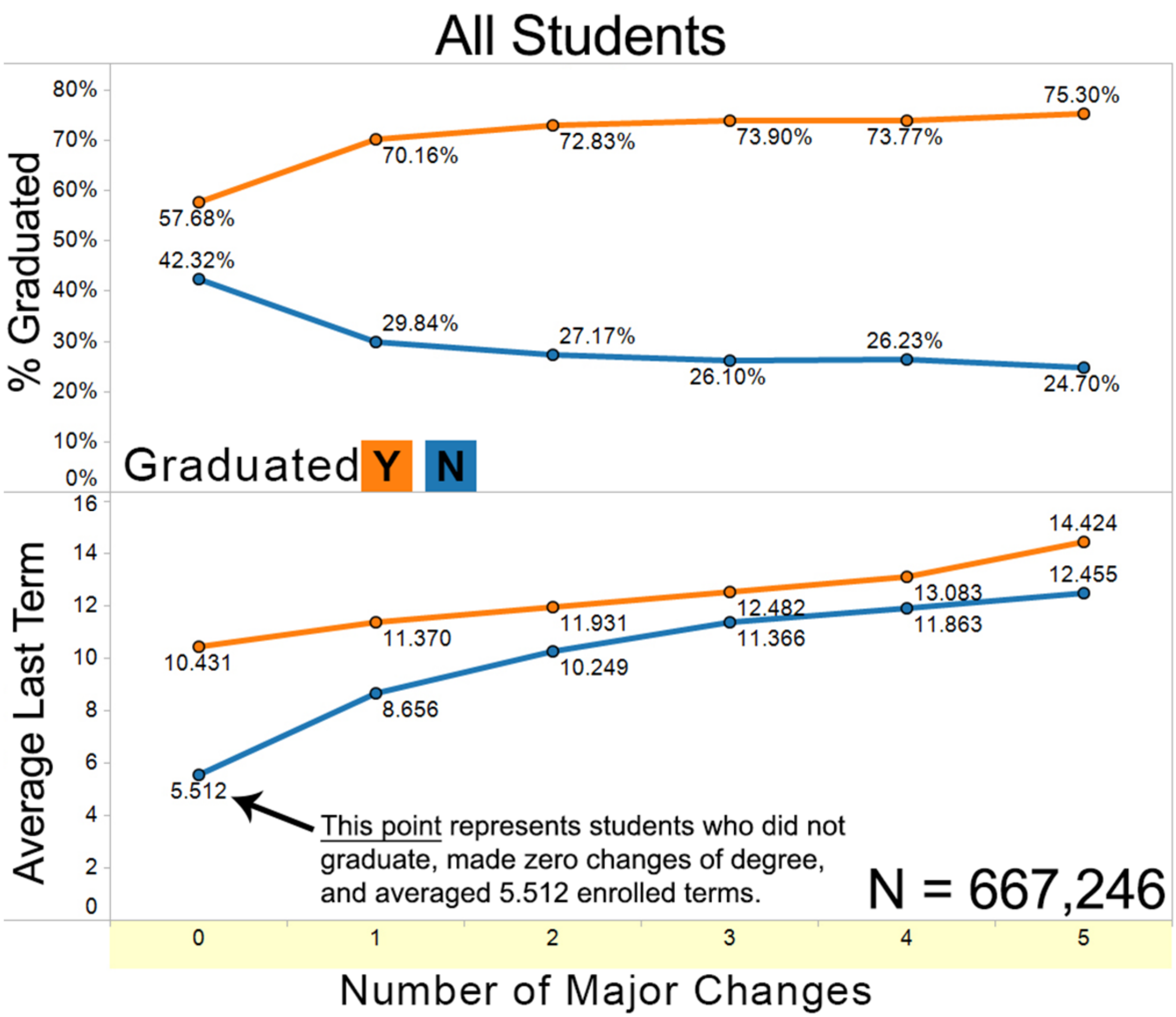

Figure 1. Number of major changes graphed against average last term and percent graduation for all students.

4.2.2 Finding Two: The Penalty in Time to Graduation is Nearly Linear Per Unit Major Change for Most Major Types of Change Sets

On a large scale, it appears that most major changes yield some sort of per-enrolled-term *penalty*. The nature and description of this penalty will be extrapolated in the discussion section, but has the potential to become convoluted. Figure 2 shows all incoming engineering students, and it demonstrates the linear relationship for the first four major declarations in the graph in the lower pane.

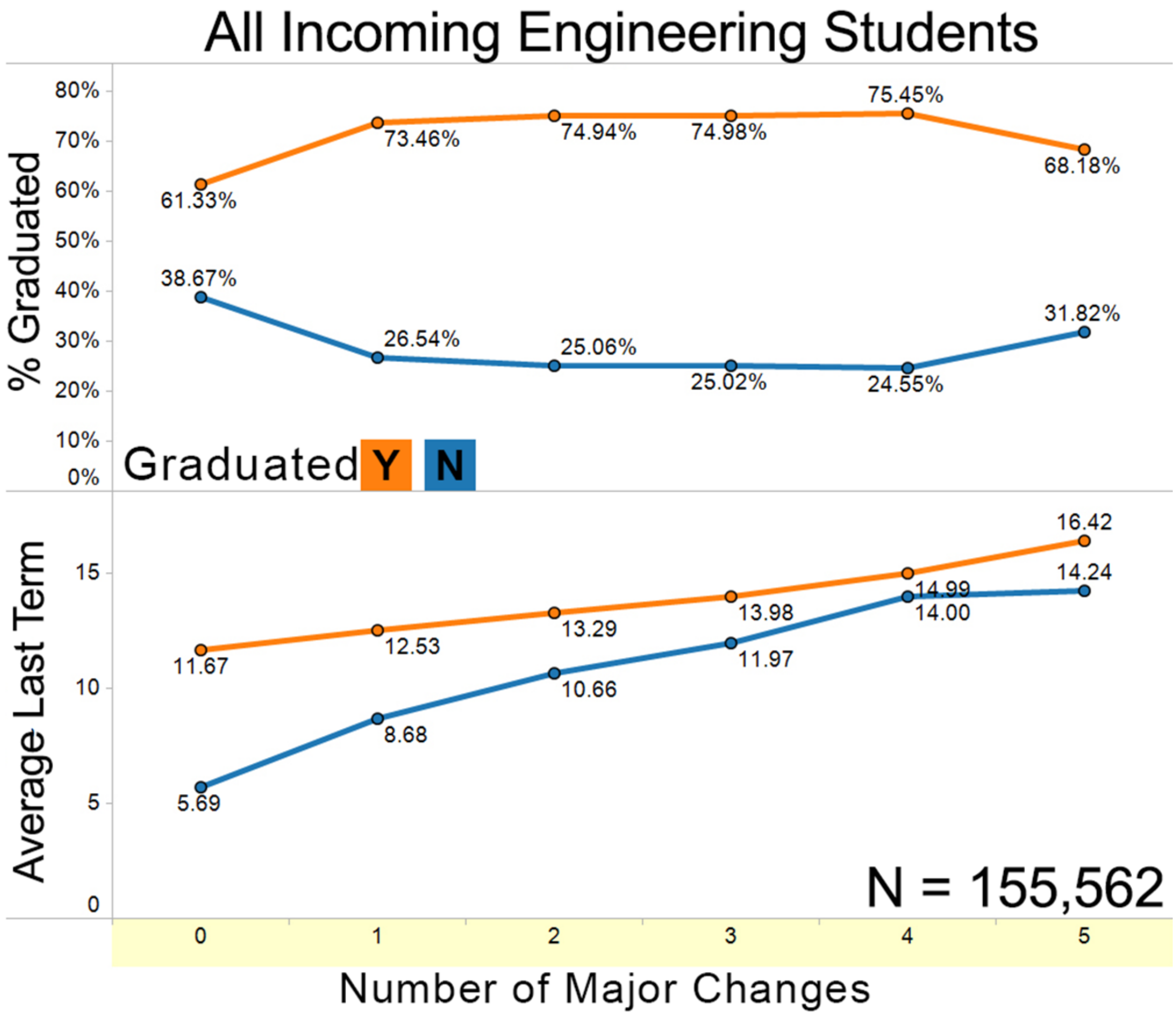

Figure 2. All incoming engineering students.

4.2.3 Finding Three: Even Among Students Who Drop Out, Switching Takes Time

Students who drop out after switching majors take longer to drop out than students who drop out without switching majors. By itself, this conclusion has meaning. It is expected based on number two, but should still be made explicit. Using Figure 3 as an example. The amount of time in terms enrolled a drop-out student greatly increases after the first switch, and increases in a linear fashion until the five changes. The issue at five changes is that the population size drops precipitously.

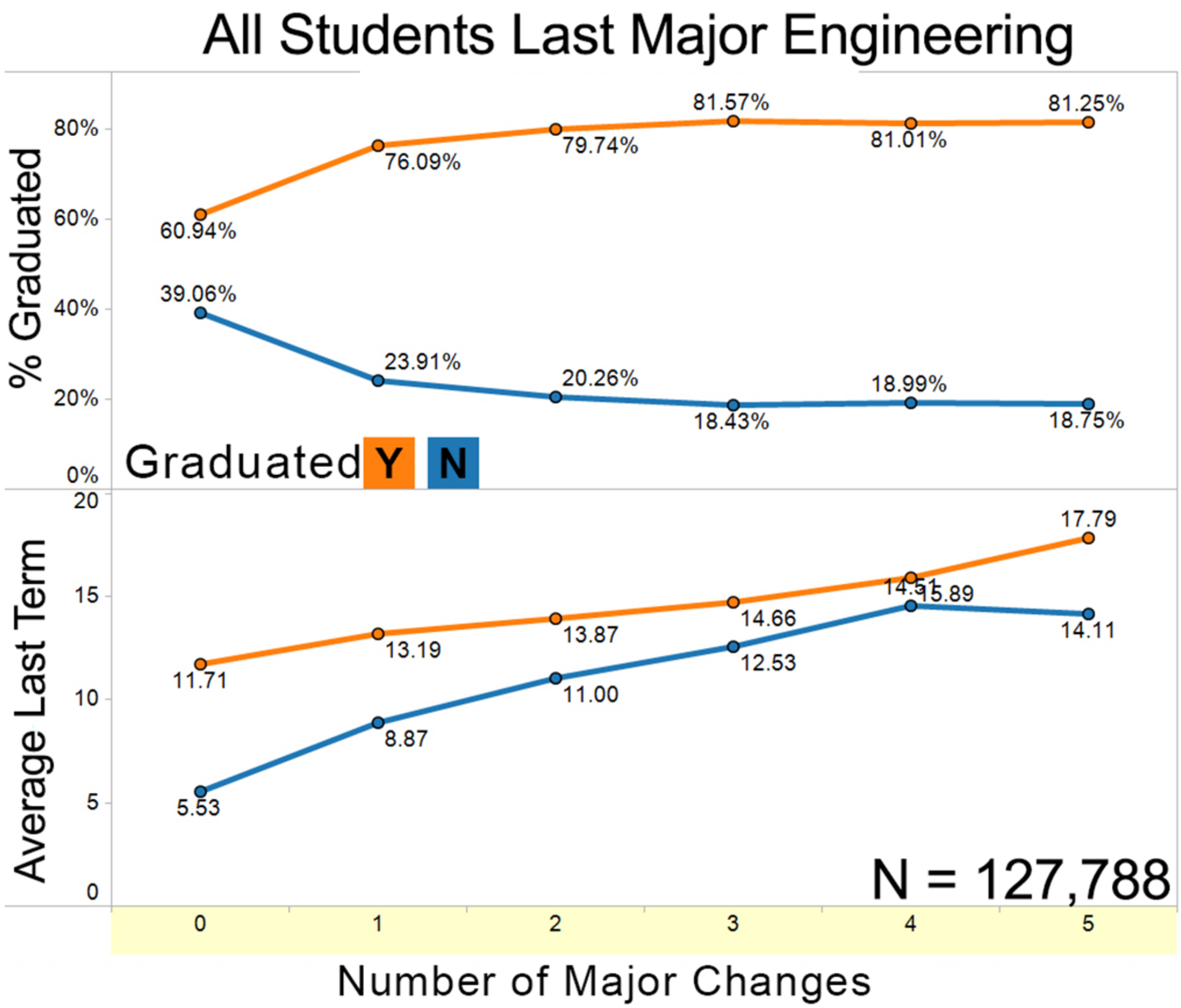

Figure 3. All students whose last major is engineering.

4.2.4 Finding Four: Students Who Switch More Accrue a Stronger Time Enrollment Penalty If They Drop Out Than Those Who Stay.

This is a completely untraversed segment of the educational landscape on this scale. Another way of putting this is that if one looks at any of the graphs, the slope of the line for the drop outs is steeper than for those who graduated. While there are theories of cohort cohesiveness within engineering and within education as a whole, there are no theories of dropouts extending along multiple major changes and accruing more of a penalty per change than those who stay. This finding does not suggest that students should be advised to stay in engineering beyond their motivation to succeed, but it does remind advisors and students that the time and effort that students have already invested in the engineering curriculum make it more likely that they will succeed by staying in engineering than trying to get settled in another major. Students who are struggling in engineering who switch to a non-engineering major not only face the challenge of adjusting to a new major, but they face the possibility that they might struggle in that major as well due to root causes that are not specific to engineering.

Students who “stay,” in this case, are those who graduate. They are the successful students who obtained their degrees. The successful students, from all of the graphs, always have a higher number of terms enrolled until graduation than those who did not succeed. After a few switches, the gap in overall time enrolled seems to close a bit. The problem is that without further qualitative analysis, it is impossible to know just how different those who graduated are after a few changes from those who dropped out.

Figure 4 demonstrates this phenomenon for students starting and ending in an engineering major. Once again, although the penalty per major switch is greater for the students who dropped out, they still take less time to drop out than those who graduated, and it is impossible to say why they took that much time.

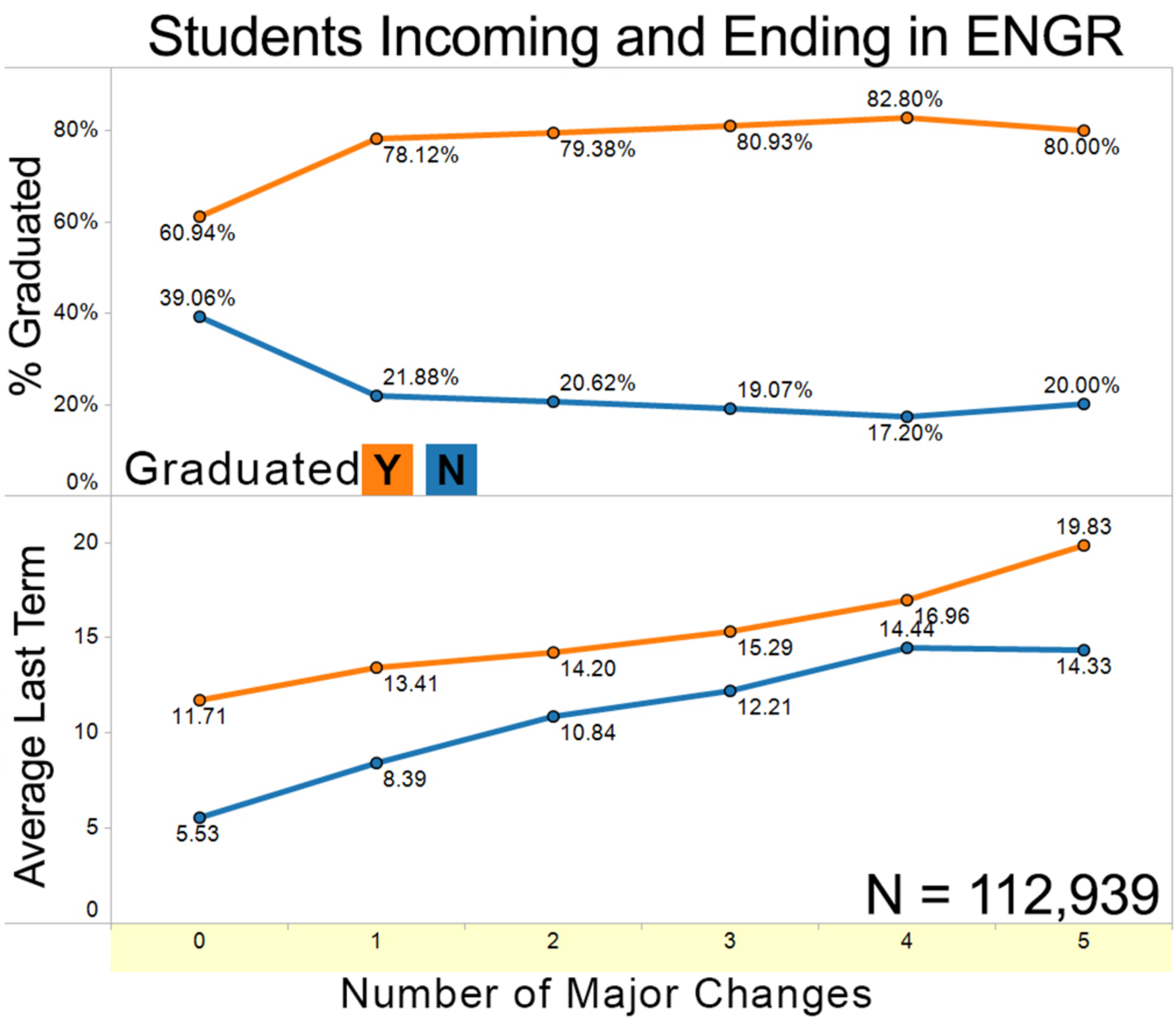

Figure 4. Students who begin and end in engineering.

4.2.5 Finding Five: Students Whose Last Major is an Engineering Major Who Wwitched Majors (Including Switching from Another Engineering Major) Take Less Time to Succeed, but More Time to Fail

So if a student starts anywhere and ends in engineering, the penalty for changing majors is less than if that student started and ended in engineering for a successful student but worse for an unsuccessful student. Figure 3 and Figure 4 demonstrate this. if one starts anywhere and ends in engineering, the penalty for changing is less than if one started and ended in engineering for a successful students but worse for an unsuccessful student, and Figure 3 and Figure 4 demonstrate this. The orange line in

Figure 3 shows that a student switching majors takes a shorter time to graduate if he came from anywhere but engineering and graduate in engineering than if he started in engineering itself. The blue line in Figure 3 shows that those same types of students take longer to drop out than a student in Figure 4. Graph 4. It is no surprise that students who drop out of engineering after switching into it suffer significant penalties—the pathway into engineering is narrow, and students who do this lose a lot of time adapting to the rigid engineering curriculum, only to abandon it. The other finding is more surprising—that students who graduate after switching into engineering graduate more quickly than students who switch among different engineering majors. This may suggest that courses in non-engineering majors can be used to satisfy general education requirements if a student switches into engineering—but that engineering courses are not as easily counted in other majors – even other engineering majors.

For subtle comparisons, Figures 5 and 6 are included here to show the differences for those started in anything but engineering and graduated in any degree and those who started in non-engineering and graduated in engineering.

.

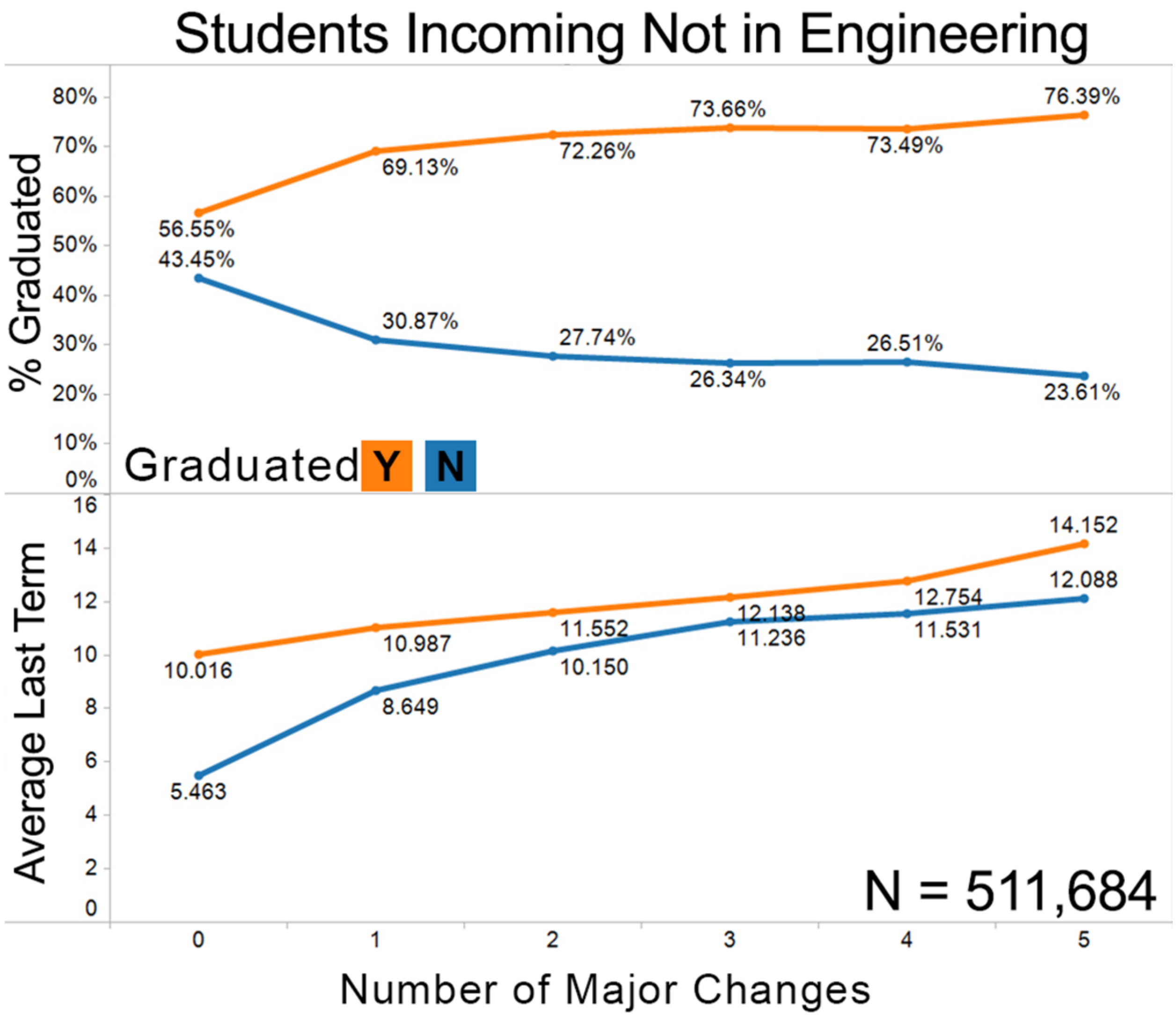

Figure 5. Students who begin in a major that is not engineering.

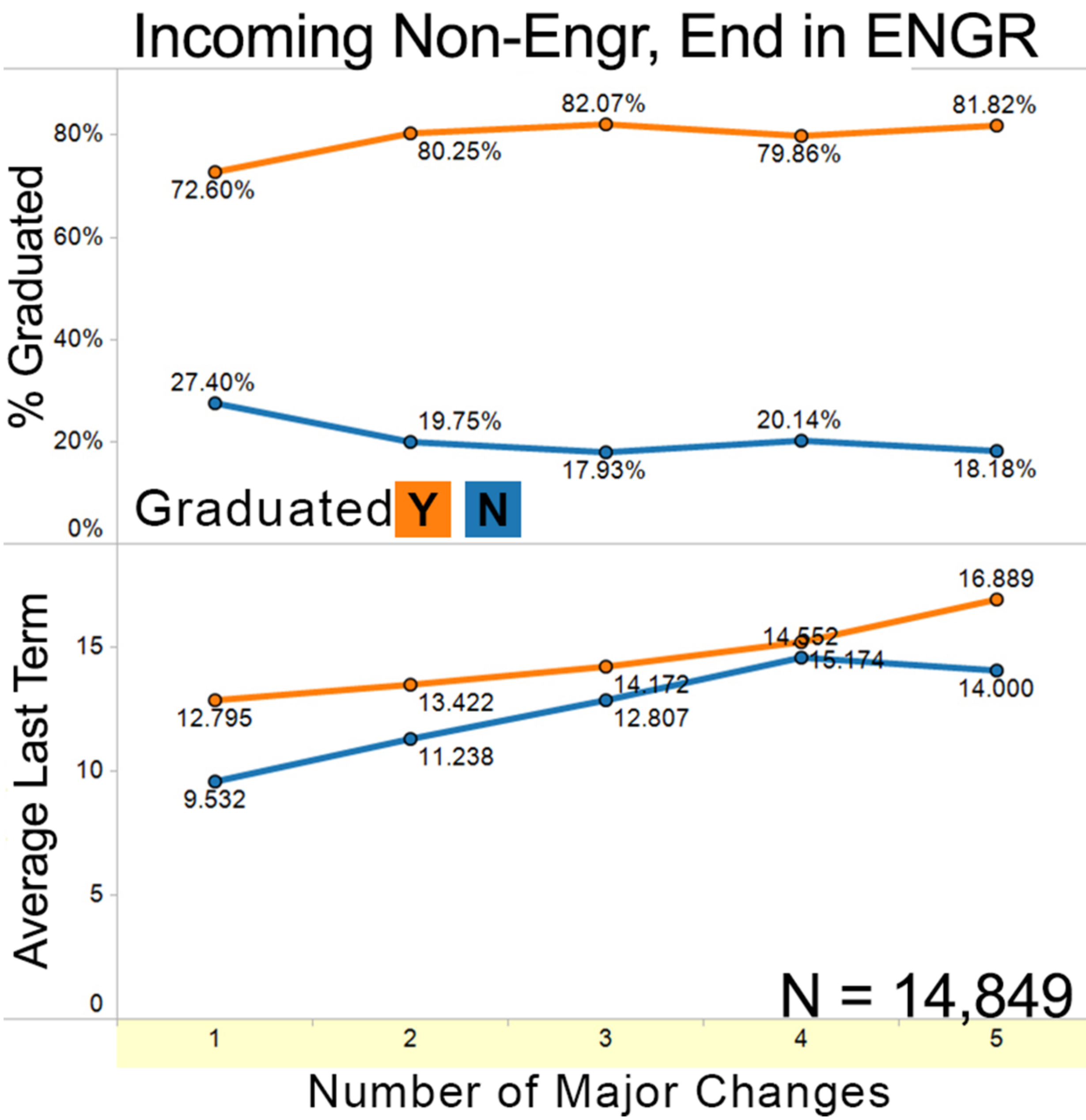

Figure 6. Students who started in a non-engineering major who ended in engineering.

4.2.6 Finding Six: Students Graduating in Anything Other Than Engineering Have a Higher Attrition Rate Overall Per Switch.

Borrowing on previous MIDFIELD work and extending it to major changing, this is easily realized (Ohland et al., 2008). MIDFIELD has already established that engineering students have the lowest overall rate of attrition. It is not surprising that when looking at multiple changes of degree, that engineers would have the lowest overall average.

Figure 7 is a perfect example of Finding 6, as it shows students who never even “touched” an engineering major throughout their college careers. The difference in attrition/graduation rates between Figure 7 and the other graphs is noticeable and significant.

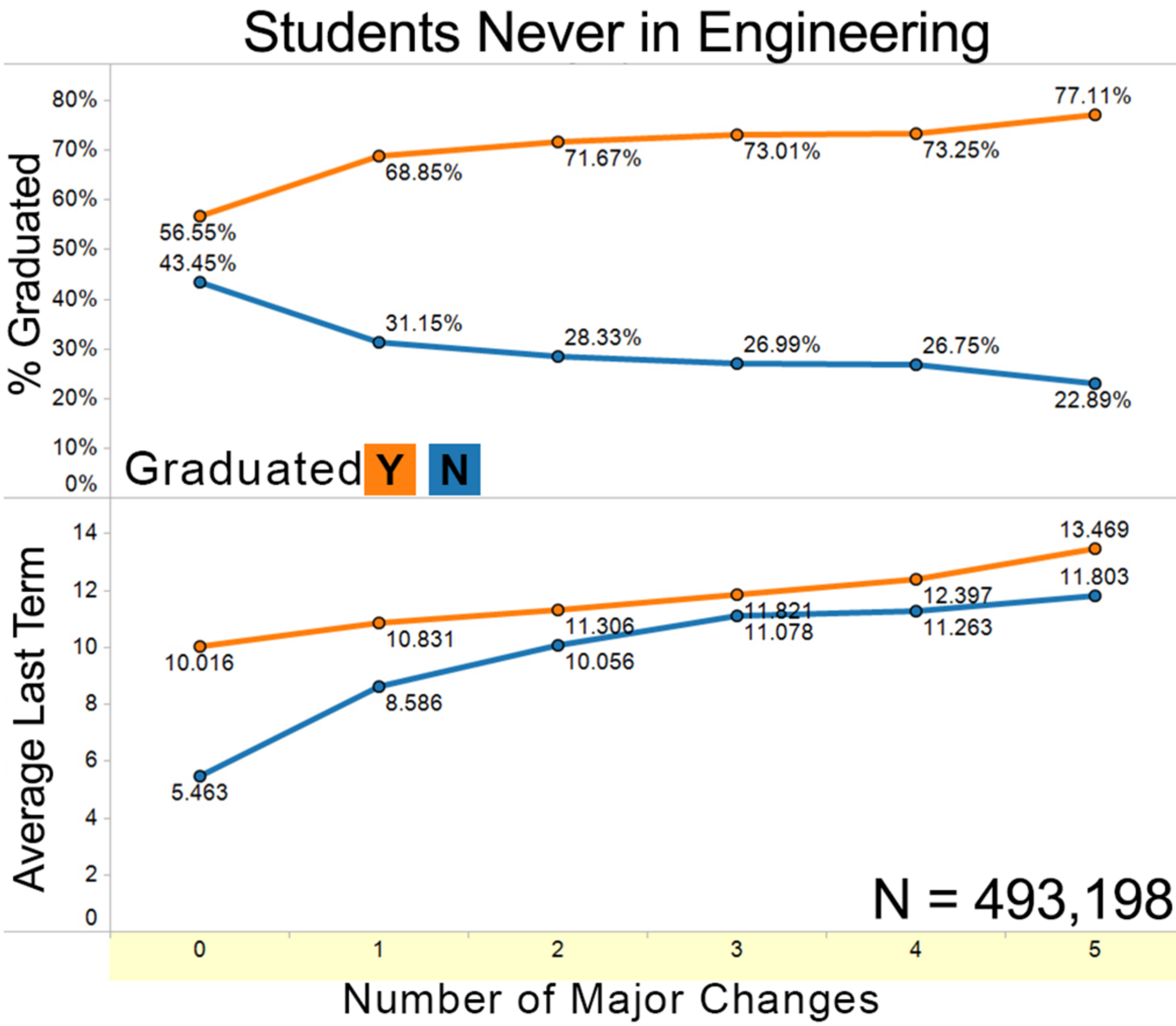

Figure 7. Students who never enrolled in an engineering major.

4.2.7 Finding Seven: Students Graduating in Anything Other Than Engineering Take a Significantly Lower Time to Graduate Than Those Graduating in Engineering.

Unsurprisingly, when extended into the realm of major changing, the results of nearly every cross-sectional analysis on engineering and time-to-degree hold. Figure 7 supports this finding.

4.2.8 Finding Eight: Students Who Matriculated into Engineering Whose Last Major is Engineering Have the Worst Penalty forTerms If They Drop Out within Three Changes

Figure 6 directly demonstrates this finding. If a student matriculates into engineering, there is a strong *hump* to overcome. Students in this situation take longer to drop out than any other group studies in this research as a whole until four major changes. If I weigh by overall number of students, the patterns holds until five changes.

4.2.9 Finding Nine: Students from FYE Programs Have the Highest Average Terms Enrolled Rate at Zero and One Change If They Drop Out

This result is slightly unexpected. Remember, that in this treatment this means that when they incurred their first change they left their directed path. A first change would be accrued for a student who left FYE and moved on to electrical engineering and then to another major afterwards. If the student left FYE and changed to a non-engineering major, that would also count as one change. Look at the number of terms in Figure 8 for students who came from FYE programs. For those students, they take longer to drop out than other groups of students.

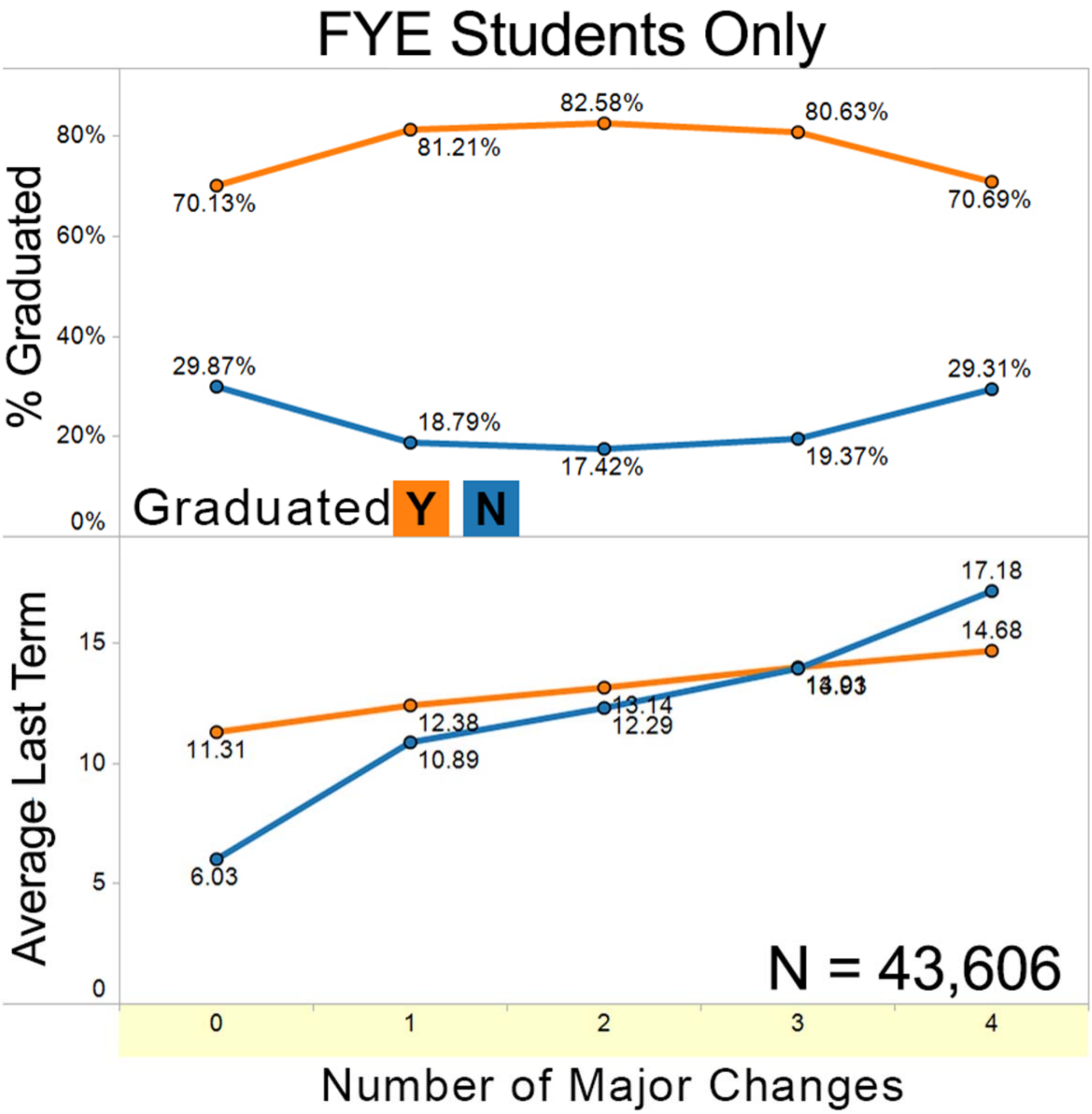

Figure 8. First year engineering students only.

4.2.10 Finding Ten: Students from FYE Programs Make Excellent Progress to Graduation When They Switch Once

To be expected, those students who come from a focused program do well even when they switch majors. So while FYE students take longer to drop out of college, they have a higher chance of graduating overall after they switch.

4.2.11 Finding Eleven: Undecided Students Are Doing Fine Concerning Graduation Rates

With all of the concern of some papers about undecided students needing special interventions and to be treated as a separate class of student altogether, they appear to be doing fine concerning graduation rates. Figure 9 shows that once they switch from undecided into anything else, their graduation rate is higher than many other student pathways discussed here.

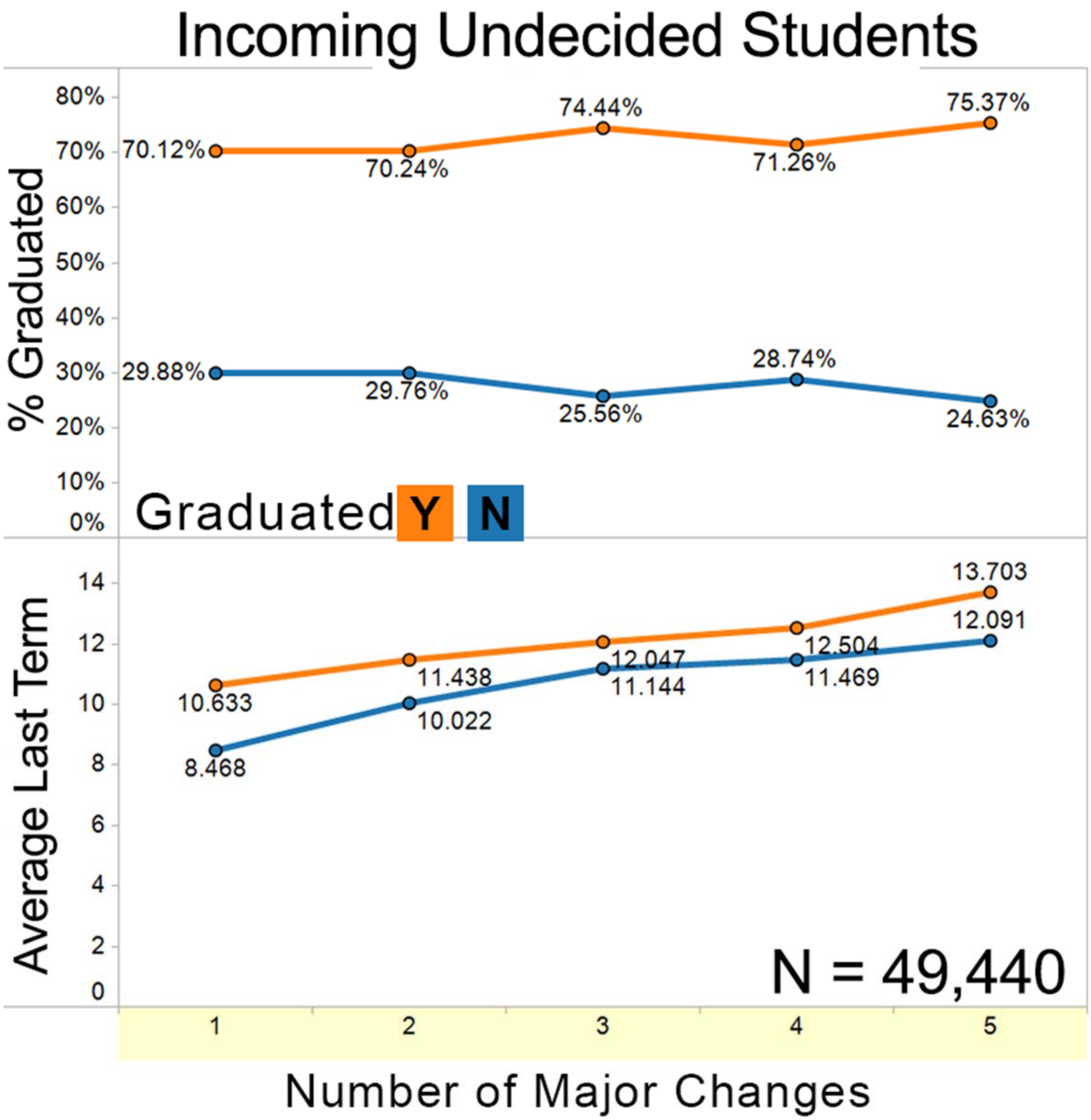

Figure 9. Students who started with a major of undecided.

4.2.12 Finding Twelve: For Those Switchers Who Stay Only Within Engineering Majors, the Graduation Rates Are High

Figure 10 shows how that for students who change majors from one engineering discipline to another, that the graduation rates are significantly higher than for other groups of major switchers. The value of 78.09% after one change is the highest for any figure presented here.

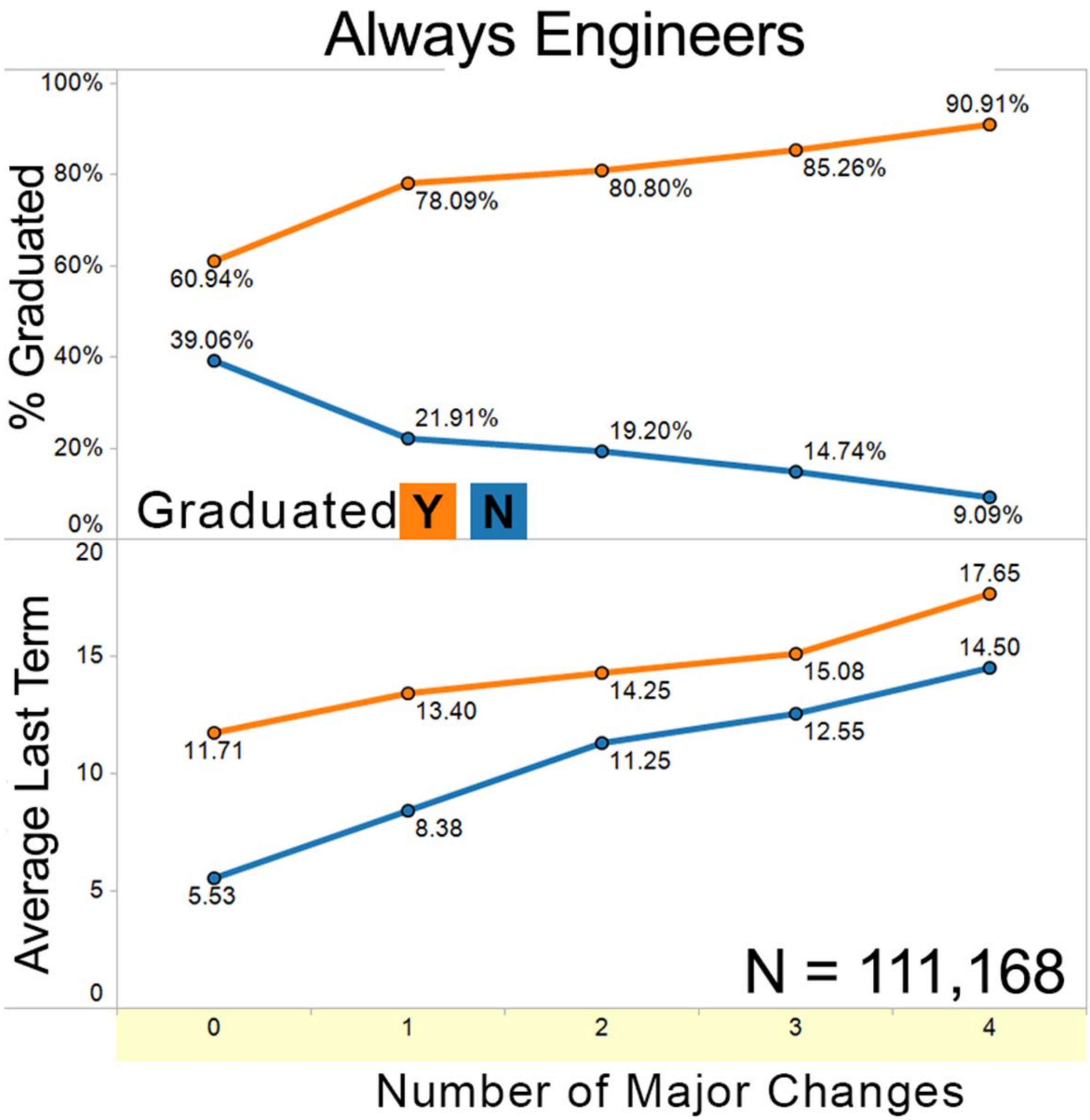

Figure 10. Students always enrolled in an engineering major.

The next set of conclusions revolves around the curricular sets metric and the data set described in the previous section. The goal of this data set is to probe overall curricular *flexibility* and to determine if there are some more favorable pathways for engineering student success. Here, the "complete set" means the student who traverses the curriculum without a single exception to the coursework, (defined by a "YYYYYY" in his record).

4.2.13 Finding Thirteen: By Far, the Most Traversed Curricular Pathway is the Complete Set

This makes perfectly good sense and validates the existence of published curricula. If students didn't follow them at all, there would be a severe issue. As Figure 11 shows, (or in this case doesn't show,) approximately 50% of the students simply pass through the curriculum with all of the required courses on the books. In a way, this is difficult to believe, as that means that some schools have more than 50% of their students looking completely "normative" on paper. The implications for policymakers at such schools are daunting. In fact, any time a large-scale, curricular change is proposed at such a school, a dean would have the ability to look at a chart such as Figure 11 and say, "Well a majority of students and the largest segment of students are doing fine with the curriculum as it is, so there's no need for change."

4.2.14 Finding Fourteen: Every Possible Exception to a Complete Curricular Set is Represented in Student Behavior

This speaks to the diversity of student pathways. Every possible combination out of the 128 has been traversed, with some more rare than others.

4.2.15 Finding Fifteen: The Most Popular Pathways Show Consistency—with Few or Many Semesters with Incomplete Curricular Sets

Of the top configurations for curricular flexibility, all seven of the configurations that only had one curricular set missing were in the top ten of most frequented graduation pathways. The only exceptions were students with an incomplete second and third semester's curricula and students with a complete first semester curricula and who had all other semesters incomplete.

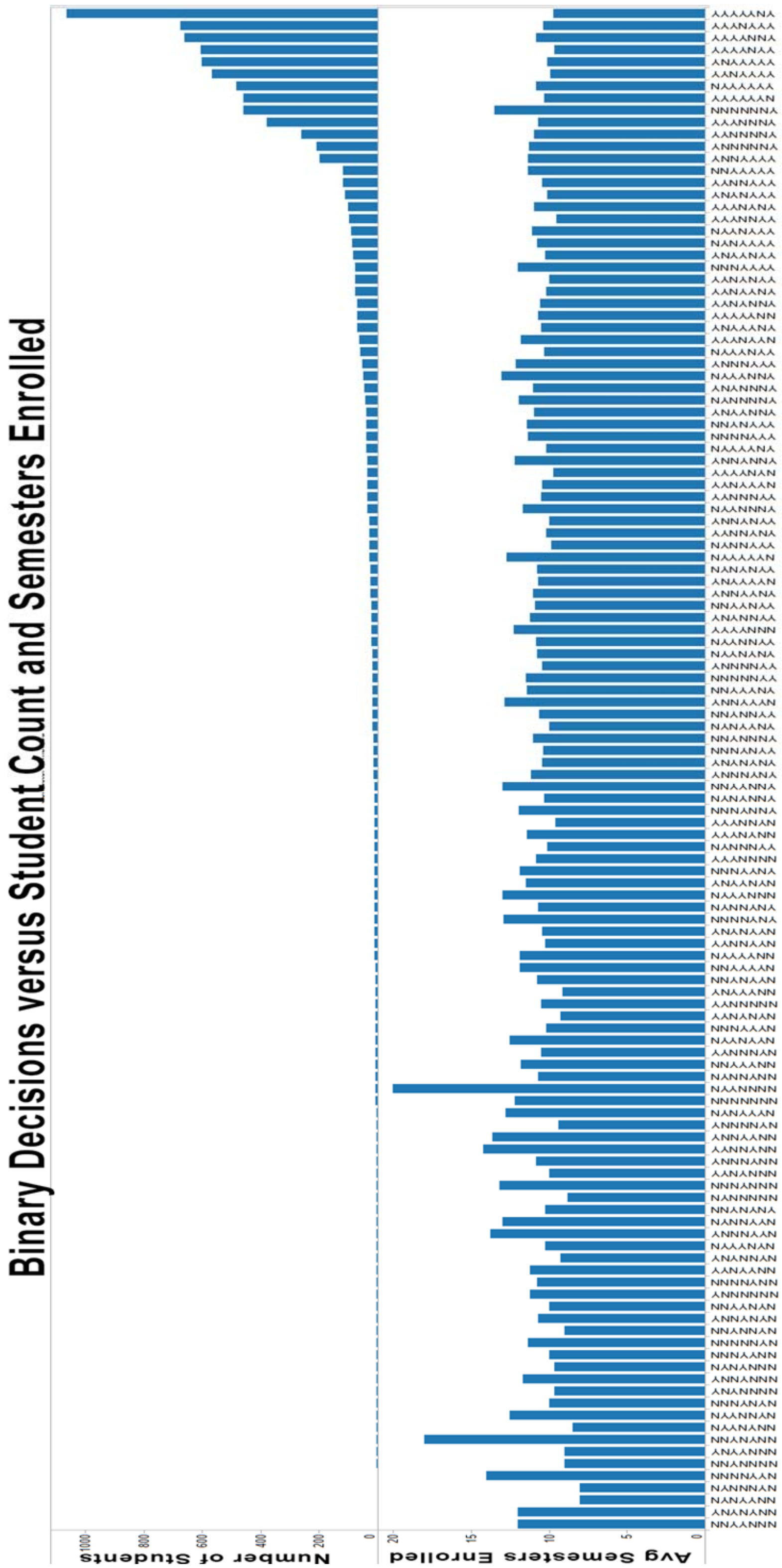

Figure 11. Binary decisions graphed versus overall student numbers and average number of semesters enrolled. The “YYYYYYY” column is left out as it compromised ~50% of the overall number of students.

4.2.16 Finding Sixteen: The First Semester isn't the Most Common Semester to Lack Documentation of Completion

Students might lack records of completion due to credit for testing out, Advanced Placement, International Baccalaureate, dual enrollment, small number of transfer credits, and more. These exceptions are most likely to affect the curricular set for the first semester, yet the first semester is not the most commonly incomplete set.

4.2.17 Finding Seventeen: The Order of the Ys or Ns in the Completion Pathway a Student Takes Does Not Necessarily Correlate to a Longer or Shorter Stay at the University

While there are pathways that are more normative than not, simply looking at the overall curricular pathway yields little information as to the overall number of semesters a student will be enrolled. If, for instance, one looks at all of the students with three Ys and four Ns, the order of them does not seem to make a difference. Part of this is that the overall number of students who may traverse a course such as YYYNNNN may be exponentially greater than the number of students who traverse NNNNYYY, thus putting the researcher at the mercy of counting error.

4.2.18 Finding Eighteen: Students Who Exercise More Flexibility in Their Curricular Pathway Accrue a Time Penalty to Graduate

When aggregating all of the possible combinations where one, two, three, and etc. exceptions are made, a pattern emerges. Almost counter-intuitively, students who take advantage of the flexibility within the system accrue a penalty to graduate. This finding as exhibited in Figure 12 is a succinct summary of the entire methodology behind the curricular sets metric. It demonstrates irrefutably that while there are myriad ways to graduate and a majority of students take advantage of the flexibility of the system, the more a student takes advantage of the flexibility, the longer it takes a student to graduate. The net contention of this discovery is that students as a whole who game the system are doing so either because they need to graduate (aka they are extenders) or the system has accommodated them for some reason in order to push them out since they are "good enough."

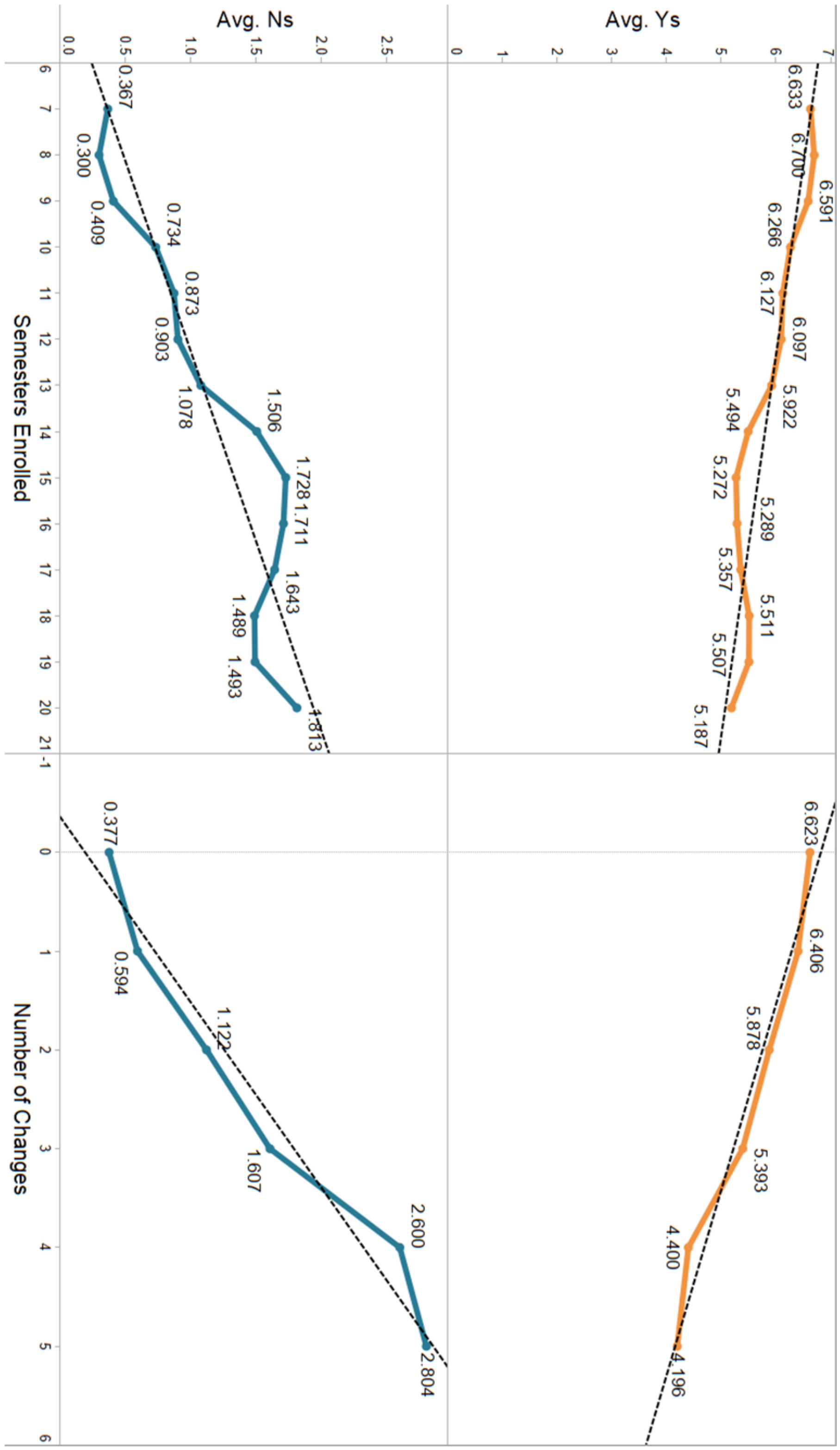

Figure 12. The relationship between major changes and semesters enrolled and the average number of Ys and Ns.

CHAPTER 5. DISCUSSION

5.1 A Short Overview

In engineering education, it is possible to segment up a discussion into the following sticking points: what we know; what we think we know; what we think; and what we found.

There are essentially a few topics of discussion that bar attention at this junction: first, the direct discussion of which theories apply to the results at hand; second, why metrics matter and the choice of metric being of key importance; and third, a larger discussion on the role of educational theory. The third point here comes from a longstanding tradition of educational theory being expansive and at times overarching. While it is beyond the scope of this work to summarize the history of educational theory, within the realm of major changes, this paper presents the case that there is little to no unified theory on major change.

The dearth of actual information may stem from a lack of educational theories surrounding major change or vice a versa. While it certainly is possible that educational theories on major change have predicted some of the results here, their lack of comprehensive longitudinal data leaves much to be desired in the way of empirically affirming or overthrowing their assumptions. Take, for instance, the theory presented in the literature review of coursework latency. Surely, it would seem logical that students, when traversing between two similar or even divergent majors would have lengths of time where they taking courses in two major pathways, but where is the overarching evidence given multiple schools and multiple colleges to test the theory? It simply does not exist in any longitudinal format.

5.2 The Penalty for Shifting Majors

The ubiquitous result held universally constant throughout this work is the penalty for shifting majors. While some groups appear to have a stronger penalty for the shift given when along certain bulk pathways, the nature of the major shift itself is important to note. Furthermore, where this shift comes from for any group of students can be the source of multiple qualitative studies.

As outlined in the literature review, numerous publications have touched upon the subject of delaying a major change, shifting majors, or remaining undecided as a contentious issue from the point of view of an undergraduate's career trajectory. That being said, there are two classifications of declaration on the subject: the explicitly declared penalty; and the implicitly declared penalty. Sometimes, papers simply addressed the problem of major shift indirectly by constructing a similar but not completely related metric. Other times, they addressed it within a model.

Starting with the most recent article on major shifts by George-Jackson (George-Jackson, 2011), the goal of this paper itself is not to assert a penalty for switching majors, although that is the net contention of its results. The originally stated purpose by George-Jackson, that of filling in a gap in our understanding of where students *go to* after they leave the STEM fields, with particular reference to the trajectory of women, is noble but not entirely novel. The cross-tabulations of George-Jackson's work are of interest here, as they note the beginning and ending majors for all of their student groups. Previous MIDFIELD works has touched upon the subject of the attrition of female students as well as the conundrum of attracting students to the engineering discipline, from both the persistence and overall quantity viewpoint.

Another challenge of George-Jackson's work is the lack of an explicit term system or a time system. The use of a static metric of time disaggregates the data to an extent that makes it somewhat difficult to interpret. Whereas my work is directly related to the terms given by a university's registrar, George-Jackson's work is partitioned into one-year time frames. The difference is essentially the same between a histogram treatment of major penalties and an actual aggregate that would take advantage of a longitudinal data set. Certainly, it is doubtful that George-Jackson did not have access to the number of semesters these students were enrolled in the given institution. It would add significantly greater resolution to have such a chart instead of simply a yearly metric one.

George-Jackson's results are consistent with mine in the sense that she discovers that success or *persistence* rate of students even after a shift who remained in the sciences is quite high. She also concludes that the systemic problem of attracting students to the sciences is an issue, a result discussed at length in other MIDFIELD papers. Her work is superior to mine in the sense that she tracks explicitly from one change where a student goes within the science framework she has constructed – a level of detail available to us but not currently probed in this work. She notes that after the switch, women tend to complete their degrees faster than men, leaving open the idea of sex segregation in major shifts.

Giesey's paper on his work at Ohio University, while small in nature as most in the subject are, yields two comparative results: first, that the overall number of students who shift major may be low relative to the total number of students in an institution; and second, that the penalty for changing majors is significant. The issue with Giesey's work is that the students who shifted majors were not seemingly chosen in any logical fashion. While it could be argued they are representative of the number of students who shifted major within the larger sample, that, too is debatable, as he offers no explicit reasoning if they were chosen implicitly or explicitly for their major changing quality. Also, given the high number of the 111 students in his sample that were transfers (17), who dropped out (only 7), who were co-op students (28), and who enrolled in some sort of remedial credit course (41), it's difficult to believe this is a representative sample of Ohio University's student body.

Giesey sheds light on the fact that for some institutions the shift of major may be a cause or an effect. For instance, while simply looking at raw statistics within his paper, the students who shifted majors incurred the largest penalty in time-to-degree in years

(6.28 years relative to 5.15 for the average), yet he does not explicitly count the shift in major as a cause of any sort of delay in graduation,

> The most significant reason for increased time-to-degree appears to be the difference between the credit hours that students attempted and the credit-hours students earned due to failing, withdrawing from, and repeating courses. Students averaged 12.1 credit-hours in involuntary repeating (credits failed and mandatory repeats) and another 10.3 credit-hours in voluntary repeating or withdrawal (withdrawal passing and withdrawal failing). This represents well over one quarter's work (p.227).

Complicating things further, while these major-changing students had a higher number of credit hours failed relative to every other population probed by Giesey (except those whose GPAs were in the bottom quarter of their cohort,) they also had the highest number of credit hours completed (258.8 quarter hours relative to 238.6 for the average). Giesey falls short of concluding any real impetus for why students shift majors, he just uses those who do as a category. Even their GPA (2.92) is close to the average (3.0,) making it difficult to extrapolate from his findings to any real relationship between major shift and curricular success or failure.

The small study by Gordon in 1992 at Ohio State University, although not explicitly just about major changes, does indicate another indirect mechanism via which students may opt to switch majors. Gordon's entire paper consists of the frustrations and dire consequences endured by students who are, literally, men and women without a major in an institution that is categorically oversubscribed. In a large institution, it may be typical to have one hundred students at one time dealing with oversubscription issues, but at this particular time in OSU's history, they over 1,000 students without majors. Gordon did not make mention of any sort of penalty for shifting majors under these circumstances. In fact, he explicitly noted that forcing a student to make changes early led to deleterious consequences in the form of not only poor major choice, but wasted time.

Another indirect explanation comes from Kramer's work at Brigham Young University. He noticed a few things about students who shifted majors. First, the majority of students shifted major from their original choice, a conjecture supported by my work. While not included in any graphics, of the large colleges within the MIDFIELD database, those within the engineering community have nearly a 50% total chance of making at least one major change if I aggregate all major changes and average them among engineering students. Every other large segment of the university population has a higher per-capita change. Second, a majority of students shifted from their initial college of choice to another college altogether within the university! While I cannot completely support this hypothesis, trans-college mobility is high, and inter-college mobility is not well understood. Within the engineering population alone in this study, approximately 111,167 total students were always engineers, while only 21,702 of them who changed majors shifted only within the engineering college. So I can conclude at least for engineering students in a very rudimentary way that they have a greater chance of switching majors outside of their engineering college more so than within it. Third, the students who did not declare a major upon matriculation had a significantly lower chance of shifting majors later in their career. While I will not present results analogous to the third conjecture here, it is true that for undecided students, they have a stronger probability of switching once and as soon as possible, along with a very high graduation percentage thereafter. The net contention of these facts leads us to conclude that the inherent penalty for shifting majors may not be related to either being undecided or choosing a major early in one's career.

Kramer also makes the suggestion that the bulk of major changes occur in the junior (32%) and senior (14%) years of a student's career. The main bone of contention with this research is two-fold: first, the definition of junior and senior year is not clear from his work; second, the institutional policies of Brigham Young play an extreme effect in engendering the situation. While the timing of major changes is not a topic I have presented here, preliminary analysis into the subject using MIDFIELD data suggests that no matter what institutional policy is in place at any of the MIDFIELD schools, students shift as early as they are allowed. While it is true that being undecided may have a slight factor, aggregated over many students, the vast majority of students declare and shift a major at the first possible convenience, (aka, after their first successfully enrolled term).

The work of Micceri does not completely support my hypothesis here that there is an inherent penalty in switching majors. While analyzing the seven cohorts in the University of South Florida, Micceri notices nearly no difference between those who switched once, twice, three or more times, and zero times and concludes that the "data do not suggest that a greater number of major changes substantially increase the time to degree" (p.4). That being said, the difference between those with no changes in time-to-degree is 4.80 years and those with three or more changes is 5.03 years, so the change exists, but it is subtle. Statistically speaking, Micceri offers no insight as to whether or not the statistical difference between the sets is meaningful or not.

The penalty Micceri does observe that runs congruent to my observations is an increase in time if a degree is not achieved, increasing from 3.42 years for no major change to 4.64 for one change and 5.18 for two major changes. Translating into total terms and comparing to my data for all students in MIDFIELD (divorced from time in years), a jump of 3.42 years to 4.64 years can be thought of as an increase in one year, whereas my jump of 5.51 terms to 8.66 terms coincides roughly with one year. The shift from 4.64 years to 5.18 years is approximately 0.6 of a year, which in discrete time must be more than one term, and our jump from 8.66 terms to 10.25 is between one and two discrete terms.

Where Micceri agrees with this work is within his treatment of the probability of graduation and frequency of change. The claim that "change your major and double your graduation chances," which comes directly from the title of his 2001 paper, belies the point that, in fact, students within his data set did just that. The caveat behind this claim once again is that students at his home institution were subjected to an institutional policy that did not allow them to change majors until after being enrolled for two successful terms. Regardless of institutional policy or not, the fact is that my data completely agrees with Micceri's statement. In fact, it does so across all schools and across all major pathway categories I classified here. Finally, Micceri notes that of all of the bulk student major classifications, engineers change majors the lowest number of times on average, a result in agreeance with my observations.

Another penalty of sorts almost entirely ignored in the literature other than a few qualitative studies is the penalty for transferring into engineering from a non-engineering major. Within MIDFIELD, we are well aware of the lack of *attraction* that exists within engineering, and even less is known on what students who matriculate into engineering from elsewhere due within its confines. Molnar at Purdue concluded in a study that students who transfer into engineering from elsewhere have the lowest interest in engineering of all groups, (including engineering students who leave) (Molnar and Delauret.R.J., 1973). He hypothesized that due to curricular and GPA issues, transferring students from outside of engineering would have a different "drive to become engineers" (p. 56), thus leading to potentially greater drop-out rates or a higher rate of attrition in terms of enrollment semesters. Examining such issues in the light of major changes may be interesting. After the primary major shift, it is apparent that students entering engineering from non-engineering backgrounds fair exceedingly well, with a 72.6% chance of graduating and a 13.4 average number of terms enrolled. While the percent of graduating for an engineering major who shift once and stays within engineering to graduate is 78.1%, his or her average number of terms enrolled is 13.4, indicating that students coming in from the outside of engineering do so on a similar time frame to those who are within the engineering framework.

The real penalty between those who always stayed in engineering and those who came into engineering from the outside is in the overall number of terms enrolled until dropping out. Those who stayed within engineering take an average of 5.5, 8.4, and 11.3 terms for zero, one, and two major shifts, whereas those who matriculate from the outside take 9.5 and 11.2 terms for one and two shifts. This appears to mean that while there is an initial hump for those who come in, it appears that once they are integrated into the engineering fold, they drop out at the same time.

While not discussing a *time* penalty for major changing, the seminal works of Theophilidies and Warren cite a possible GPA relationship. Theophilides' research points to high GPA among the group of students he labels as "non-changers," a phenomenon not supported by MIDFIELD data on any large scale. Also, his work supports the congruency of major commitment to non-changing status. While I cannot test that result with MIDFIELD, it is fairly obvious from other research results that such a conclusion is not universal. Warren differentiates between non-changers, double major changers, and minor changers based on GPA and finds a significant correlation between high GPA and non-changers. The caveat with Warren's work is that a high GPA only protects against a major change in general. It does not differentiate between categories of major change. Also, Warren's work deals entirely with a population of National Merit Scholarship recipients, which is indeed not a representative sample population.

Linking curricular design to a penalty in terms of time, Titley states that,

> "Curriculum designs that feature rigid and extensive area-related requirements in the first two years preclude exploration and often lead to a setback in time and in some cases feelings of failure or indecisiveness when a given student shifts to another major" (p. 297).

This statement links my two sets of analyses together in a coherent fashion. The concept that curricular organization has a direct effect on student indecisiveness is not well understood or discussed throughout the literature. Titley's conjecture from his research supports the notion that when a student shifts majors, the curriculum effects more so than student ineptness or unpreparedness can affect the overall time a student spends "catching up," which is certainly one impetus that drives the overall terms to degree rate up per major change. His proposition is more highly reinforced by the fact that the vast majority of major changes occur within the first two years of the MIDFIELD data set, a time when most students are focusing on completing core requirements for their majors and not when they are focused on completing advanced coursework.

5.3 Chilly Climate Cause and Effect

One blatant theoretical issue that must be addressed is the treatment of the success of the major shifter him- or herself. It is of significant surprise to discover that other than the time penalty, those who switch more frequently enjoy a much higher rate of success than those who do not. While individual departments and colleges vary, what is the net contention of such a sweeping result for so many students? One striking issue within engineering education is the straw man of attrition, which previous MIDFIELD work has shown to be no more of a problem for the engineering colleges than any other set of disciplines. The issue at hand is that perhaps we have become so good at alienating students on a micro and macroscopic level, that institutions as a whole have become flexible in accommodating the students who change majors to better ensure their success. The inverse may also be true, that somehow we have simply tolerated a less-than-ideal environment on so many smaller levels because the net effect of a student shifting majors, more often than not by a significant degree, is their increased probability of graduating? Surely, the effect of “failed” students in one field going on to be quite successful in another can solidify in the minds of the original field’s professors that their curricular litmus tests are indeed effective at weeding out the students who do not belong. When students who do not belong shift fields and are successful elsewhere, administrators may see this as a sign that departmental policies are indeed intelligent and have been put into place for a reason.

The pervasiveness of academic alternative programs as described by Gordon and Steele’s work, along with a treatment of major changers as being an at risk population, only further calcify the notion that we as an academic enterprise are supporting the second half of the major change phenomenon – dealing with the matriculating student – and ignoring the departing student. Of course, this flies in the face of the work of Tinto and others, who have spent their entire careers understanding student attrition.

5.4 Bulk Pathways

Much has been written about the pathway issue within engineering education. Of particular note is the work of Atman who waxes philosophically about how “There are not that many pathways into engineering (p. 23)" (Atman et al., 2009). Of concern to this work is the overall success of students who traverse within engineering on a large scale. There is no research on students who perpetually shift throughout multiple changes and exactly how they are succeeding or not succeeding. Figure 4 clearly outlines a simple methodology to address such a problem. I find in Figure 4 that students who start and end in engineering as a whole outperform the graduation rates of other large-scale groups. Percentage wise, through five changes, they appear to be doing quite well. While MIDFIELD work notes that the engineering disciplines have the lowest total matriculation of all discipline groups, students within engineering do quite well and students who enter engineering from outside maintain a high percentage graduation rate throughout multiple major changes.

5.5 The Timing of the Shift Itself

Elliot and Titley both believe that the shift in majors is most likely to occur at the second year of a student's career. The work of Micceri bodes well with Titley, in fact, Micceri's entire premise of his first paper on major change is that there is an explicit reward for shifting majors (Micceri, 2001). The problem with such a declaration is that within one school or set of schools with the same policy, the policy completely dominates the shift of major. In the case of Micceri's 2001 work, the institutional policy of not allowing students to change until after two semesters enrolled, is arguably a huge impetus for the effect of students changing immediately after the bulk of their core courses are finished. Combining the work of Micceri with the results here, I can theorize that since students apparently do exceedingly well after they change majors once, if institutional policies delay that major change, it is of no small gap of logic to assume that whenever they switch, they will have a higher chance of graduating than if they stayed in whatever major they chose or was chosen for them upon matriculation. The very nature of the ubiquitous jump in major graduation percentages leads to that conclusion.

While I did not address this factor explicitly, it is evident from George-Jackson's work that students may switch later than previously thought. In George-Jackson's work, students who only shifted once did so in their fourth and fifth years at a much higher rate than at any other time (45.9% and 40.1%, respectively). Although, the main bone of contention here is that George-Jackson's work encompasses only one change, whereas Titley's did not. Another issue at hand is the strong grouping of George-Jackson's work is incompatible with most previous work on the subject, and since her work is not related to a portable, register-inspired change, it is not easily adaptable. The timing of the shift of major change is one area where George-Jackson's methodology has an advantage to my treatment. Even though she only treats one major change, she does track it as to what academic year the change takes place.

Gordon furthermore concludes that institutional policy of not directing students properly, allowing them to progress until their junior year simply because they may not have any "flag" such as a large number of complete semester hours while being undecided, is directly responsible for the issue. Gordon not only reinforces the ideas behind George-Jackson's observations, but when coupled with Titley and Micceri's I uncover that there is a debate within the community as to the direct consequences of institutional policy and not only if a student chooses to change majors, but also when a student chooses.

Kramer discovered that the timing of changes is important, and 32% of the students who changed majors at Brigham Young did so during their junior year, and 14% of those changed during their senior year. As in George-Jackson's case, I conclude that this is due to institutional policy and not a student driven phenomenon. The probabilities of nearly 50% of all major changes occurring late in a student's career are not supported by MIDFIELD under any large-scale circumstances probed so far.

Pierson's conclusion that the majority of students make their first change within their first (29%) and second years (45%) of college aligns more with what MIDFIELD sees. Also, Pierson in his Purdue survey noticed that students routinely make poor curricular decisions, whether they involve choosing a major or otherwise. Sometimes these poor decisions related to their future career alignment and other times they related to simply how little they knew about their major decision.

5.6 In Relation to Metrics

One interesting concept to convey here is the notion of why metrics are important and how they should be constructed. Both Astin in his treatment of cross-section versus longitudinal (Astin and Denson, 2009) metrics and seminal works in hierarchical linear modeling (Raudenbush and Bryk, 2001) refer to one concept that is paramount for the construction of any metric, the concept of what I call *zeroth* order. This can be viewed two ways: first, it means that all metrics must have availability to the base level of a system; and second, the aggregate of such a metric should be meaningful. Sometimes individuals take for granted how an aggregate is meaningful. An example would be second-order aggregates of sex, which can and cannot be statistically significant. Sometimes, what a researcher really wants as an aggregate of sex is really an indicator of a low number of one particular sex in a large group.

Throughout the literature I see anecdotal and sometimes direct evidence of the issues of students in engineering having one defining moment that convinces them to stay or leave. The inverse, of course, presents a much different viewpoint of engineering culture; that Despite the warnings of researchers claiming that undecided students are not performing at some horrible level relative to their peers (Lewallen, 1993; Titley and Titley, 1980), and that pushing students into choices prematurely does not solve any problems (Brown and Strange, 1981), the problem is pervasive.

On a macroscopic level, certainly one way to prevent attrition while attenuating the number of students who remain undecided is to provide opportunities where students are able to develop their allegiances to a major or college. Wessel's theory of affective commitment speaks to the concept of agency in engineering education, and shows that students who feel an affiliation to their field of study do not change. More importantly, the students stay within their major because they believe they are responsible for choosing why they enrolled, which is why it is an affiliation heavily related to the concept of personal choice.

Lewallen's work can assuage any of the alarmists who believe that major changing is a huge shift in a student's career trajectory or life path, especially with regard to undecided students. He firmly believes that institutional policies should reflect the fact that "Being undecided is not the exception, but rather the norm" (p. 110). As demonstrated by my data, undecided students fair quite well once they've chosen a major, and Lewallen concurs that being "initially undecided" does not present a great danger to a student's academic career. Also, the assertion by Lewallen that students have been indoctrinated to believe that there is a seemingly one-to-one ratio between major and career choice presents a problem for those students who wish for their curricula to present a modicum of flexibility. In fact, because being convinced of one's initial major accounted for so little of the variance in persistence, Lewallen leaves open the question of what other metrics could be used to probe major success.

Where my work supports that of Kramer's is in the treatment of the undecided drop-out student and his overall time to degree. It appears that undecided students, after they declare, have a significantly lower time-to-degree than the student average in terms declared. One caveat that may derail the results of Kramer is the interesting increase he cites in the over number of semester terms until graduation for students during the course of his study. It increases 8.9 semester to 11.3 semesters of an eight year period, while the average rate of major change per semesters holds relatively constant (from 0.15 to 0.19). I have not observed such a phenomenon in MIDFIELD, although the possibility of the average terms increasing without an analogous change in the number of major changes is an effect worthy of future qualitative and quantitative analysis.

Of key importance here is deciphering just what "intent" to major really means. Micceri explicitly comes out and declares that "First semester intention" (p. 4) may be a horrible predictor of graduation rates and time to degree, not simply due to a period of change in a student's life, but due to the nebulous nature of the term itself. Another paper that takes a more productive view on the major related outcome is Wessel. Wessel defines the "major related" outcome as any outcome affecting the major, and not simply failure to succeed within the major itself.

Gordon's and Steele's work on retention of major changes at The Ohio State University is indicative of the problem pervasive within major shift research: the notion that somehow those who change majors are akin to undecided students; and that undecided students are somehow anathema. Of course, Gordon and Steele are not responsible for the treatment of undecided students as vulnerable population, this treatment in modern academic times originates around the research of Abel (Abel, 1966), although with less pronounced immediacy. As an example, Abel's work revolved around the *certainty* of engineering students concerning their chosen career trajectory. Abel's main formulation served to warn administrators and students on the perils of choosing a major based simply on GPA, persistence, or graduation rates. While the *certainty* of a student directly correlated in his low sample rate to attrition in engineering, they made no sweeping statements that the undecided (or even "failed") student should be treated as an at risk case.

Steele on the other hand, explicitly says that undecided students after their first year are an "at risk" population. The first caveat concerning Steele's research is that the main impetus for his work is that The Ohio State University, during the time of his study, had an oversubscription rate of more than one thousand students! If that number does not alone seem high, an oversubscription rate means, literally, that over one thousand students could not enter a major of their choice (or even an alternative major). By binning undecided students into one of the "flags" for placement into an alternative academic advising program, Gordon and Steele overlook the facts from nearly all the other papers reviewed here that undecided students by themselves seem to do quite well once they make a decision on their major. Also, there is the issue of the latency effect in Allen's work applied to the undecided student, an effect also almost completely unmentioned throughout the literature. There may be subsets of the undecided students who are enrolled in multiple course trajectories while attempting to figure out which major fits them best. Students in such a conundrum would be easily flagged under Gordon and Steele's academic alternative advising system instead of being thought of as simply trying possible majors.

TItley's papers discuss major changing as less of a factor of being undecided and more of a *discontinuity*, which has two benefits: first, it explicitly addresses the institutional pressures on a student who may be between two sets of curricula; and second, it gives the student credit for intelligence. Unlike Gordon and Steele and even other researchers, Titley's entire body of work revolves around the notion of *crystallization* (Ginzberg, 1951). This methodology treats the concept of major shifts as a student coming into his own, and not necessarily indicative of a hard, life-changing decision. He explicitly warns against faculty and staff treating the undecided major or major undecidedness as a sign of "academic ineptness" and "negative indecisiveness" (p.297) instead of a developmental process.

Also, Titley's assertion that general studies students, once allowed to choose a major, have a lower chance of dropping out than the average student can be supported by my work – even when compared to engineering students! Consider that in this research I allowed FYE students a "free pass." FYE students could choose whatever major they wanted after enrolling in FYE and it did not count as an explicit choice whereas undecided students did not have that privilege. Given this information, Figure 9 makes undecided students' completion rate after their initial choice high relative to other groups.

The novel treatment of discontinuities in academic pathways provided by Ewert speaks to both curricular origins of student consternation and major changes. Although Ewert does not accurately describe his database, he treats all major changes as a disruption and compares the disrupted student pathway to the continuous student pathway for all students in the NELS:1994 database. The problem with such an analysis is that it is extremely difficult to compare to MIDFIELD due to an over-reduction of the data itself. All discontinuities are binned up across all years, with the exception of students who only had the flag of "part time enrollment for more than six months" flagged. While this paper does shed light on a possible issue of sex segregation and curricular completion, because it has been overly reduced, it is a good example of a paper in the field that cannot be utilized.

5.7 The Misunderstood Nature of the Latency Effect

Allen's assertion of the latency effect is correct in that it is poorly understood. Given the types of data available to researchers and just from a glance at Table 1, one can imagine that most registrars do an exceedingly poor job of reporting double majors on a large scale. Of course, one way that the latency effect comes into play within my work is the nature of the penalty for drop outs. It appears that there is a net penalty for students who matriculate into a highly technical field such as engineering from the outside from comparing Figures 6 and 10. The initial "bump" in overall time to drop out may in reality be students floundering under the pressures of traversing overcoming the initial *shock* of two separate cores. All MIDFIELD schools have some sort of engineering core, albeit some less onerous than others, the core issues still exist. If I couple this with the supergraph of overall flexibility versus semesters enrollment, I can surmise that a student attempting to exploit flexibility in the system in order to graduate may be in line for a rude awakening. Students within the normative pathway described in the curricular flexibility supergraph already have an increasingly difficult time if they have mismatching elements required for graduation relative to what is required for graduation, and I can only hypothesize at this time, but I would guess with high certainty that a student matriculating into a highly technical field would suffer even more of a penalty in terms of enrollment time if he or she possessed greater flexibility.

5.8 Flexibility and Curricular Change

While I have tried wherever possible to avoid falling into the trap of associating the two, it is impossible to realistically divorce courses and curriculum, although every cross sectional metric in higher education does so. When individual courses are studied, the results are usually extremely focused on either one myopic regime or at best a sequence of courses (Felder et al., 1997). When groups of courses are studied, the primary method is to determine "course loading" metrics, which amount to nothing more than a basic head count of how many students did or did not take enough credit hours to move towards their second year of study.(Reyna et al., 2010) With the current concern about flexibility in assessment metrics to study such populations as commuters

(Kuh, 2001), a curricular set metric as proposed here is one novel solution to such an assessment problem.

Even though the problem arising from curricular flexibility is seemingly counterintuitive, the argument it addresses is important. When state and federal officials simply wish to cut courses from the curricula and claim this lowers the average enrollment time, this map provides a strong, overarching argument against such thinking. For instance, if a school simply attempts to open up more exceptions to the curriculum, will it really be lowering overall student enrollment time or will it simply be inviting those students who are already overenrolled to game the system? The point is that there is an effect that has not been properly addressed on a large scale that may have deleterious consequences for administrators who attempt to change institution-level or college-level curricular requirements with the thinking that increasing flexibility will produce the singular effect of lowering enrollment times.

The argument here is that this is a snapshot of what students who *already gamed the system* did during their career on the path to graduation. This is not a picture of students who are responding to dynamic changes attempting to help them graduate on time. Then again, every school within my database had made policy changes during the years in question here, so it’s not fair to say that the students weren’t responding to policy changes while exploiting or discovering the flexibility in their majors. In fact, one could say that the students took advantage of every possible source of flexibility in order to maximize the benefit if one has particular faith in the competence of students who have not exactly taken the normative pathway. In any circumstance, for anyone to claim that students are simply static beings would be audacious at this juncture. Of course, the entire point of the navigational flexibility theory proposed by Stevens is that students are keen enough to perceive and exploit unofficial methods of traversing the degree pathway.

There is no general theory of curricular flexibility, but a few authors from education have provided us with tools to construct the basics in light of my research. While Robinson’s metric is not comparable to mine and cannot possibly measure the types of phenomenon I observe, it is the first, large-scale attempt at creating a curricular path metric akin to those presented here in Figures 11 and 12. As discussed previously, the main issue between Robinson's treatment of curricular progression and mine is multi-faceted, but form an administrative point of view, her treatment does provide a quick glance into large-scale student pathways and does provide an aggregate-scaling solution for large data set.

Treatments by researchers such as Goldrick-Rab, Frehill, and Ewert concerning pathways are concerned with the important concepts of sex and racial segregation mechanisms at play and their effect on student curricular progression. While studying sex-segregation issues are important to my research, accurately describing on a large scale the penalties for *flexibility* is an open problem.

Stevens' work coins the term most accurately reflecting my treatment of curricular sets – navigational flexibility. Of prime concern is the divide between the *official* and *unofficial* mechanisms for traversing the curriculum, and is a relativistic treatment of the student experience. Examples of students taking roundabout ways of cutting through the course curriculum abound, such as students with access to previous examinations provided by upperclassmen or through their fraternities, but what is the net contention of students who actually do have coursework flexibility? The only solution offered by this theory is that a majority of students follow the normative path and that is why it is normative, while I should properly assume that there are a cohort of students who will find non-normative paths and succeed through taking them. In this manner, the theory is completely in alignment with Figures 11 and 12. The normative pathways are normative by definition; furthermore, deviation from the normative pathway by exercising flexibility places one outside of the mean and accrues a penalty. Stevens' work even ponders the divide between the first two years of coursework and advanced coursework more likely pertaining to a student's major, but does not really offer much in terms of a operationalization pathway. Probably the main failing of the development of navigational flexibility by Stevens is the failure to establish a replacement for the pipeline metaphor from which he "seeks to recover" students (p.365).

Figures 11 and 12 shed light on the issue of flexibility from a large scale point of view. Figure 11 shows the overall distribution of students with various exceptions, and one can notice that when it comes to overall time to graduation, the chart appears to be almost a noisy one. The idea of the first, two years of coursework being somehow a time divider is not readily apparent in my analysis. In fact, if one accounts for simple counting error, there are no outliers as far as average time to graduation in enrolled semesters in Figure 11. What this indicates is that any of these large-scale curricular paths, by themselves, is not very illuminating other than from an overall counting point of view. From such a viewpoint, I find that the normative pathway dominates, (it is not displayed, but it is nearly half of the total number of students,) but it is not the majority of students, indicating that most students have at least one missing curricular set.

It is easy to overlook the powerful conclusion that the *normative* pathway dominates. On its own, this is to be expected, but when view in light of Figure 12, another layer of complexity emerges. Regardless of all of the previous discussion on major change, how being undecided is not a detriment to one's career, and etc, Figure 12 painfully illustrates how simply not deviating from the curriculum as recorded in the registrar's book is the easiest path to graduate. Also, it shows how an increase in flexibility is related to an increase in curricular flexibility.

Another large-scale consequence of deviating from the normative pathway is that while researchers such as Stevens have suggested that we should inject "real" engineering experiences into the curricula, the curricula as it stands currently is self-propagating. It is a system that may defend itself by punishing those who dare to exercise from the established pathway. After all, there's a reason why we have a set curricula and there's a reason why a strong percentage of students follow it or only veer slightly from it by having only semester's curriculum incomplete. For the curricular set "YNNNNNN," which has a large number of students, I can immediately see that it is an outlier as far as average number of terms enrolled relative to the other members of the top ten configurations.

Another interesting result from the flexibility Figure 11 is that there is no foreseeable disadvantage to having a flexible course earlier or later in one's academic career. This result compares to the conclusions provided by Szafran. In Szafran's work, while difficulty affected student retention, it had no bearing on a student's trajectory and, in fact, advising students on avoiding difficult courses was definitely not in the student's best interest. In my work, I find that flexibility of later, more difficult courses, does not yield an advantage over flexibility over earlier ones for students who graduate. Of course, the picture for students who do not graduate may be radically different and most likely is.

5.9 The Nature of Small Studies

One particular issue at hand is the nature of the small study. One particular example is the work of Giesey (Giesey and Manhire, 2003). From a simple introduction, his work, which covers time-to-degree, seems promising in that it may containing significant information on students who changed majors until he states,

> This research was conducted at Ohio University (OU), which is a Research-II Carnegie classification, state-supported university with an enrollment of 27,798 students on one main and five regional campuses. OU has 276 undergraduate degree programs and a retention rate of 85 percent. Due to its rural location, the student body is largely residential (1 percent of freshman are classified as commuter students) and traditional-aged (74 percent are between the ages of 18 and 22). The population for the study consisted of 111 students who completed BSEE degree requirements between June 1996 and March 1999 (p.276).

Such disappointments are commonplace when searching for information about major shifts, and make the nature of many studies difficult to extrapolate. Not only does Giesey's study seem surprisingly small relative to the overall amount of data that was available to him from the registrar, it is certainly not a representative sample of the institution he studied. It is nearly impossible to believe that of the 111 students he probed, more than 20% of them were transfer students, (which he describes in his data). Even the 10% of those students who were major changers may not be at all indicative of the overall number of students at Ohio University who shift major, yet he uses major changers as one of his main study groups. The net contention of this may mean that his main groupings for students may not be relevant for his institution and may relegate his study to the bin of uselessness.

5.10 Putting It Together

The notion of *cause* and *effect* should greatly concern any researcher in the field of major change and flexibility. I would like to take the time to present two interesting viewpoints on mass action to help lead the way forward for researchers on these topics. The first I'd like to present is that of *proximal component* theory, and the second is a brief thought exercise traditionally given to sociology students in their first or second year courses that can help a digression into *causality*.

Certainly, the there is a grey area between blaming the students for their actions and the university for policies that engender various actions. While it is beyond the realm of the results of this study, understanding what repeated interactions lead a student to develop an affiliation towards a major may fit a framework such as that proposed by Buss and Kenrick in proximal component theory (Buss and Kenrick, 1998). Buss and Kenrick, who are evolutionary social psychologists, propose that all big events that steer individuals in a direction (aka components,) are dealt with by human beings through the reinforcement of proximal structures, (such as family, small groups, etc,) which change how the events affect people. Of course, the sociological responses of individuals en masse reinforce personal beliefs. In order to further the study of major flexibility and change in the future, I would like to expand upon this construct by identifying patterns of reinforcement on the student and the college end that fit the Buss and Kenrick model.

I have established that existing research on these topics is reactionary. The research centers on university responses to a problem that may or may not be directly linked to major change, but the very nature of major change and flexibility research need not be this way. The common thread among the *responses* to major issues is some sort of fear of mass failure, grade changes, or enrollment issues. These sorts of issues from at the collegiate level could be viewed as large-scale *events* affecting the arrangement of student groups into various major, major support groups, etc, whereby these students then learn or reinforce their notions of the institution. In such a model, the major construct, including the major department, professors, and coursework, could be considered *proximal* structures. The actions of the individual students within the *proximal* constructs become the *individual* construct of the Buss-Kenrick theory.

What are the core ideas and social structures that such a system creates and/or reinforces? First, the university itself is the largest element within this model. Second, the social structures range from the construct of the major itself, the enrollment process, and how the university bins students (including GPA thresholds, various regulations, etc.) Third, the base (or "core") ideas revolving around the institution itself, such as research and teaching. All three of these constructs combine to form a sociological *component* theory. It is of key importance here to note that *group* structures within symbolic interactionism and other theories of sociology tend to qualify the major as a traditional group, in the sense that a major has limiting requirements for entry, the major itself is a group that has been around for a significant amount of time, it has its own rituals, and various conventional normatives and behaviours. I argue that when an institution's alignment between its core ideas conflicts with its social structures, that the university suffers on a large scale. Ex., a university claims it is a teaching institution, but cannot find homes for all of its students within fundamental bodies necessary to their survival (aka majors,) which leads to the large-scale, almost ecological component of the *institution* suffering.

What are the recurrent episodes that bridge the component to the individual? Coursework could be considered both a direct function of the social structure of organizing students into their homes that are called "majors." The coursework itself is reinforced on a daily basis and flows from directly from the students' choice of major, making it an ideal bridge from the *component* to the *individual*. There is also a feedback mechanism in the sense that the onerous qualifications for joining the group of a major within an institution may reinforce certain values or create a disdain within the student for the home institution, major, the institution's core ideas, or other individuals within the institution.

When binned into such sets, a researcher can better make determinations what behaviours of students are driven by repeated actions instigated by institutional policies or by students themselves, within and without groups. Also, an inquiring sociologist would be able to determine if some actions of students en masse are normatively defined and engendered by the group construct of the major or are some *collectivist* action. All such topics possess the common thread of determining *where the causality* is and *with whom* does it lie. Luckily, sociologists of all sorts spend endless nights conjuring up thought exercises about causality.

Differentiating between *group* and *collective* action within sociological social psychology can be exceedingly difficult, but in general, groups follow the rules I have outlined and collectivist actions tend to be non-normatively defined, shorter in temporal span, and membership transcends group limitations. Within sociology there is usually a thought exercise given in courses in social psychology revolving around the 1979 *The Who* concert, ala the legend of Wittgenstein's Poker. During this particular concert, a number of people were trampled. Various social psychologists, including Brown, have theories that pit the traditional symbolic interactionist viewpoint of collectivist action versus the ethnomethodological treatment. A traditional symbolic interactionist (S.I theorist) would posit that the fans of The Who by nature of their existence have a higher propensity towards violence, as they are base elements in the equation of violence at The Who concert. In other words, there is a very strong boundary drawn between *internal* and *external* causality within traditional S.I., with base actors taking full responsibility for their actions.

The thought exercise presented in The Who concert problem is to use an ethnomethodological approach to determine any item that may have affected the violence itself. Did the *nature* of the security cause a problem (not the security forces themselves, as they would be base actors)? What about the *style* of music, did it promote or encourage otherwise loosely affiliated individuals to violence? An inquiring ethnomethodologist would like to know if audience members of The Cleveland Orchestra may have a higher propensity towards violence if merely present within the collective at a The Who concert than other segments of society.

The way the battle between ethnomethodology and S.I. play out speaks volumes to what researchers can treat and what they ignore in the world of major change policy. Too often the research I have read revolves exclusively around the base unit, the student, in a way that ignores the hierarchical impetus of major groupings, core ideas, institutional policies, and more. In fact, in published work, I have shown that grade variance in core classes can be linked inextricably to the course in which an individual student enrolls. While focusing on the base unit of the student is definitely needed in this day and age of big data, it can also be extremely myopic, and the research of Astin has shown over a number of decades that although longitudinal data at the level of the student is necessary for understanding the academy, many variables beyond the student are needed to paint an accurate picture in educational research.

The final question really should be *how far are we willing to go in placing blame?* Once a researcher opens up to questioning large scale institutional policies, major group limitations, and core ideas, along with repeated interactions driven almost entirely by forced beyond the individual student, it becomes increasingly difficult to conclude individual students are responsible for anything beyond their own decisions, and even then they are at the mercy of structures far beyond their control

5.11 Recommendations for Advisers

After having spoken to dozens of academic advisers, I’ve noticed firsthand the problems dealt with *in the trenches* by those who seem to be accosted on all fronts with advice on how to handle student change of degree programs. I wish that the conditions at all universities were ideal, but they are not. In fact, I think that may be one of the saving graces of the American system.

5.11.1 RecommendationOne: Know the Institution.

In the battle of metrics analysis, the Astins of the world will always win. The single most important factor in understanding student data is knowing the particulars of the institution. In fact, I could say that every single one of these recommendations will flow from the qualitative argument of "know the institution." No matter how hard registrars across universities attempt to standardize parameters, there will always be unique classifications at each school. Even classifications that sound the same, "deposit only," "degree only," "co-op," "transfer," "junior status," and etc, may have radically different definitions and/or different benefits and attributes attached to them. For instance, at some schools, co-op students may benefit from having on-campus status, where they can take advantage of all facilities at a reduced student fee rate. At other schools, being on co-op means the student is practically extricated from the community until the end of his co-op term.

5.11.2 Recommendation Two: Define What the Degree Program Means to the Finest Degree Possible

The degree of "business" may mean one thing at one institution and one thing entirely different at another institution that alone is confusing enough without institutions not being specific. It is entirely important that schools use clear language with advisers and registrars to let them know what major a student is enrolled in to the finest degree possible. "Business studies" and "business leadership" are completely different things in some realms, and making blanket categories for them helps no one. "Physics" and "engineering physics" are different. "Structural engineering" or a structural engineering concentration within civil engineering can mean an entirely different world to many advisers. Without the proper information on exactly what program pathway a student is on, advisers fall prey to giving the wrong advice or sending students to the wrong place for the right advice.

Coincidentally, defining a degree doesn't mean simply telling an adviser how many hours the degree requires more so than the next most similar degree in a particular college.

5.11.3 Recommendation Three: Trust, but Verify

I have spoken with numerous advisers who cite that their supervisor or associated faculty member cited “such and such” paper and subsequently concluded that they should try that methodology at their school. Not only does this sort of behavior nearly guarantee failure, there is nearly no evidence that the paper being read had much efficacy at the host institution’s school in the first place! Nearly all of the papers reviewed here come from “small N” sources, where a good researcher could argue that the authors may have been looking at a pattern no more defining of graduation or persistence than a random walk or a noisy system.

Beyond the issue of counting error is the issue that the background of any one given paper rarely matches the background of another situation at a different school. Sometimes, papers are compared between completely different colleges as a recommendation for action. Even papers within particular majors need to be carefully read to understand the particulars of that one situation, and even if that one situation looks like a situation at another particular department at one given time, the policies that engendered that certain situation are almost never the same.

5.11.4 Recommendation Four: Understand the Deeper Meaning as to Why Students Are Being Advised

It is a categorical imperative that advisers understand the policies that have landed students in their offices. By “policies,” I mean everything from the fact that a student may have a red flag in the system from taking too few (or even too many) courses in a given semester, to a student being on the bad side of a certain administrator. Many of the papers here admitted that the students who are switching majors seem no different than those who did not switch majors, and the reason is that the institutional policies landing them in the “hot spot” of a special adviser seem to be doing a poor job at finding the right students who need an intervention.

5.11.5 Recommendation Five: Stop Treating Major Switching Students as Failures

One particular pattern seems particularly onerous in the literature, and that is the notion that students who switch majors at a particular given time in a particular given major are the same as students with either low GPAs or those with simply too many credit hours who cannot make a decision. Some of the papers have indicated that students can change majors during their senior year, and this is probably true everywhere, with good reasons or simply because they delayed it without any ulterior motive. These students shouldn't be compelled to declare a major if they do not want to, and policies that force these students to declare a major may do more harm than good.

5.11.6 Recommendation Six: If Programs that Force Students to Be Advised Have Issues, Document Them and Make Them Known

I have never read a paper where a student advisory body came back to the administration and *changed* a university-wide policy that was ineffective at targeting the right students for advising. I am guessing that these advisers either believe that their voices will not be heard or that their jobs are in peril if they say anything. Regardless, the tone of some papers indicates that when systemic issues force a number of students into an adviser's office, there is little to no plan to correct them. These sort of problems need to be front and center, as the consequences can be dire. As an example, the notion that nearly one-thousand students at a major engineering college could be without a major due to oversubscription is catastrophic and can threaten the reputation and stability of a major institution. Without the people on the frontlines properly assessing how such an issue occurred and offering advice on how to prevent it in the future, the administration of such a university is only ever looking at a small portion of the problem from which they must make a solution.

Summary

This work contains many findings that describe the effects and outcomes of changing majors and of deviating from the published curriculum and includes specific recommendations for advisers. Recommendations for curriculum designers, policy makers, and others are possible, but this work has focused on recommendations for advisers because they have the greatest role in guiding students in their academic choices.

LIST OF REFERENCES

LIST OF REFERENCES

Abel, W. H., 1966, Attrition and the Student Who is Certain: Personnel and Guidance Journal, v. 44, p. 1042-1045.

Adelman, C., 1998, Women and men of the engineering path: a model for analyses of undergraduate careers: Washington, DC, U.S. Dept. of Education : National Institute for Science Education, xii, 105 p. p.

Allen, J., and S. Robbins, 2010, Effects of Interest-Major Congruence, Motivation, and Academic Performance on Timely Degree Attainment: Journal of Counseling Psychology, v. 57, p. 23-35.

Allen, J., and S. B. Robbins, 2008, Prediction of college major persistence based on vocational interests, academic preparation, and first-year academic performance: Research in Higher Education, v. 49, p. 62-79.

Allen, J., S. B. Robbins, A. Casillas, and I. S. Oh, 2008, Third-Year College Retention and Transfer: Effects of Academic Performance, Motivation, and Social Connectedness: Research in Higher Education, v. 49, p. 647-664.

Apostal, R. A., 1968, Interests of Engineering Graduates According to Undergraduate Curricula: Personnel and Guidance Journal, v. 46, p. 909-913.

Astin, A. W., 1970a, Methodology of Research on College Impact, Part 1: Sociology of education, v. 43, p. 223-254.

Astin, A. W., 1970b, Methodology of Research on College Impact, Part 2: Sociology of education, v. 43, p. 437-468.

Astin, A. W., and N. Denson, 2009, Multi-Campus Studies of College Impact: Which Statistical Method is Appropriate?: Research in Higher Education, v. 50, p. 354-367.

Astin, A. W., and J. J. Lee, 2003, How risky are one-shot cross-sectional assessments of undergraduate students?: Research in Higher Education, v. 44, p. 657-672.

Atman, C. J., S. Sheppard, L. Fleming, R. Miller, K. Smith, R. Stevens, R. Streveler, D. Lund, and C. Loucks-Jaret, 2009, Materials for special session: Findings from the Academic Pathways Study of Engineering Undergraduates 2003--2008, Overview and Panel Discussion, American Society of Engineering Education Annual Conference, Austin, TX.

Bayer, A., 1968, The College Drop-out: Factors Affecting Senior College Completion: Sociology of Education, v. 41, p. 305-316.

Bean, J., 1990, Quantitative approaches to grounding theory in data: Using LISREL to develop a local model and theory of student attrition, American Educational Research Association, Boston.

Bean, J., and R. Bradley, 1986, Untangling and Satisfaction - Performance Relationship for College Students: Journal of Higher Education, v. 57, p. 393-412.

Bean, J. P., 1980, Dropouts and Turnover - The Synthesis and Test of a Causal Model of Student Attrition: Research in Higher Education, v. 12, p. 155-187.

Bean, J. P., and B. S. Metzner, 1985, A Conceptual Model of Nontraditional Undergraduate Student Attrition: Review of Educational Research, v. 55, p. 485-540.

Beggs, J. M., J. H. Bantham, and S. Taylor, 2008, Distinguishing the Factors Influencing a Students' Choice of Majors: College Student Journal, v. 42, p. 381-394.

Bright, J. E. H., R. G. L. Pryor, and L. Harpham, 2005, The role of chance events in career decision making: Journal of Vocational Behavior, v. 66, p. 561-576.

Brown, G. S., and C. Strange, 1981, The Relationship of Academic Major and Career Choice Status to Anxiety Among College Freshmen: Journal of Vocational Behavior, v. 19, p. 328-334.

Buss, D. M., and D. T. Kenrick, 1998, Evolutionary Social Psychology, *in* D. T. Gilbert, S. T. Fiske, and L. Gardney, eds., The Handbook of Social Psychology: Boston, McGraw-Hill, p. 982-1026.

Cosentino de Cohen, C., and N. Deterding, 2009, Widening the Net: National Estimates of Gender Disparities in Engineering: Journal of Engineering Education, v. 98, p. 211-226.

Danielak, B. A., A. Gupta, and A. Elby, 2010, The Marginalized Identities of Sense-makers: Reframing Engineering Student Retention, 2010 IEEE Frontiers in Education Conference: Frontiers in Education Conference.

Dobson, I., A. P. Haydon, and R. Sharma, 1997, Commencing undergraduates in Australian Universities: enrolment and performance trends 1993-1995, Australian Vice-Chancellors' Committee.

Duby, P., 1997, Credit Hour Loads at College Onset and Subsequent Academic Performance: A Multi-Institutional Pilot Project. AIR 1997 Annual Forum Paper / Paul Duby and Laura Schartman, Annual Forum of the Association for Institutional Research, Orlando, FL.

Educational Testing Service, 2008, A Culture of Evidence, http://www.ets.org/Media/Education_Topics/pdf/COEIII_report.pdf

Elliott, E. S., 1984, Change of Major and Academic Success: NACADA journal, v. 4, p. 39-45.

Ewert, S., 2010, Male and Female Pathways Through Four-Year Colleges: Disruption and Sex Stratification in Higher Education: American educational research journal, v. 47, p. 744-773.

Felder, R. M., G. N. Felder, and E. J. Dietz, 1997, A longitudinal study of alternative approaches to engineering education: survey of assessment results: Proceedings Frontiers in Education 1997 27th Annual Conference. Teaching and Learning in an Era of Change, 5-8 Nov. 1997, p. 1284-1289.
Felder, R. M., and L. K. Silverman, 1988, Learning and Teaching Styles in Engineering Education: Engineering Education, v. 78, p. 674-681.
Frees, E. W., 2004, Longitudinal and panel data : analysis and applications in the social sciences: Cambridge, UK ; New York, Cambridge University Press.
Frehill, L. M., 1997, Education and occupational sex segregation: The decision to major in engineering: Sociological Quarterly, v. 38, p. 225-249.
George-Jackson, C. E., 2011, STEM Switching: Examining Departures of Undergraduates\ Women in STEM Fields: Journal of Women and Minorities in Science and Engineering, v. 17, p. 149-171.
Giesey, J. J., and B. Manhire, 2003, An analysis of B.S.E.E. degree completion time at Ohio University: Journal of Engineering Education, v. 92, p. 275-275.
Gillmore, G. M., and P. H. Hoffman, 1997, The Graduation Efficiency Index: Validity and Use as an Accountability and Research Measure: Research in Higher Education, v. 38, p. 677-697.
Ginzberg, E., 1951, Occupational Choice; An Approach to a General Theory: New York, Columbia University Press.
Godfrey, E., T. Aubrey, C. Crosthwaite, and R. King, 2010, Who Leaves and When do They Go? Retention and Attrition in Engineering Education, 2010 Ieee Frontiers in Education Conference: Frontiers in Education Conference: New York, Ieee.
Godfrey, E., and L. Parker, 2010, Mapping the Cultural Landscape in Engineering Education: Journal of Engineering Education, v. 99, p. 5-22.
Goldrick-Rab, S., 2006, Following Their Every Move: An Investigation of Social-Class Differences in College Pathways: Sociology of Education., v. 79, p. 61-79.
Gordon, V. N., 1981, The Undecided Student: A Developmental Perspective: Personnel & Guidance Journal, v. 59, p. 433.
Gordon, V. N., 1992, Advising Major-Changers: Students in Transition: NACADA journal, v. 12, p. 22-27.
Gross, L. J., and E. L. Gaier, 1974, College Major and Career Choice - Retest of Holland's Theory: Journal of Vocational Behavior, v. 5, p. 209-213.
Harris, S. A., B. Golden, and S. K. Olson, 1985, A Workshop for Undecided Students: Journal of College Student Personnel, v. 26, p. 468-469.
Harrison, W., R. Streveler, R. Miller, and A. Sacks, 2006, Curriculum design for the engineer of 2020: A university community creates a public affairs curriculum for engineering undergraduates: 113th Annual ASEE Conference and Exposition, 2006, June 18, 2006 - June 21, 2006, p. Dassault Systemes; HP; Lockheed Martin; IBM; Microsoft; et al.
K, G., 1994, An Insider's Guide to Surviving Freshmen Year: Boston, MA, Suffolk University.

Kimweli, D., 1999, Choice of a major and students' appreciation of their major: College Student Journal, v. 33, p. 16-26.
Knight, W. E., and W. Arnold, 2000, Towards a Comprehensive Predictive Model of Time to Bachelor's Degree Attainment. AIR 2000 Annual Forum Paper.
Kramer, G. L., H. B. Higley, and D. Olsen, 1994, Changes in Academic Major Among Undergraduate Students: College and University, v. 69, p. 88-96.
Kreysa, P. G., 2006, The Impact of Remediation on Persistence of Under-prepared College Students: Journal of College Student Retention, v. 8, p. 251-270.
Krupka, L. R., and A. M. Vener, 1978, Career Education and the University: A Faculty Perspective: Personnel & Guidance Journal, v. 57, p. 112.
Kuh, G. D., Gonyea, R. M., & Palmer, M., 2001, The disengaged commuter student: Fact or fiction?: Commuter Perspectives, v. 27, p. 2-5.
Kupek, E., 2006, Beyond logistic regression: structural equation modelling for binary variables and its application to investigating unobserved confounders: BMC Medical Research Methodology, v. 6.
Lam, L.-P. T., 1999, Assessing Financial Aid Impacts on Time-to-Degree for Nontransfer Undergraduate Students at a Large Urban Public University. AIR 1999 Annual Forum Paper.
Lam, L.-P. T., 2007, Enrollment Patterns, Time-to-Degree, and Degree Progression for Baccalaureate Degree Recipients at a Large Urban Public University, The 47th Annual Forum of The Association for Institutional Research, Kansas City, MO.
Leppel, K., 2001, The Impact of Parental Occupation and Socioeconomic Status on Choice of College Major: Journal of family and economic issues, v. 22, p. 373-394.
Levin, J., J. Wychoff, and R. Hussey, 1994, What Students Should Know about Engineering: The Science teacher, v. 61, p. 26-29.
Lewallen, W., 1993, The Impact of Being Undecided on College-Student Persistence: Journal of College Student Development, v. 34, p. 103-112.
Lewis, E. C., L. Wolins, and J. Hogan, 1965, Interest and Abiliity Correlates of Graduation and Attrition in a College of Engineering: American educational research journal, v. 2, p. 63-74.
Long, R. A., 2008, The Multiple-Institution Database for Investigating Engineering Longitudinal Development.
Metzner, B. S., and J. P. Bean, 1987, THE ESTIMATION OF A CONCEPTUAL-MODEL OF NONTRADITIONAL UNDERGRADUATE STUDENT ATTRITION: Research in Higher Education, v. 27, p. 15-38.
Micceri, T., 2001, Change Your Major and Double Your Graduation Chances.
Molnar, G. E., and Delauret.R.J., 1973, Predicting Curriculum Mobility of Engineering Students - Comparison of Discriminant Procedures: Journal of Counseling Psychology, v. 20, p. 50-59.
National Science Board, 2008, Science and Engineering Indicators, 2008.

Ohland, M., M. Camacho, R. Layton, R. Long, S. Lord, and M. Wasburn, 2009, How we measure success makes a difference: Eight-semester persistence and graduation rates for female and male engineering students: 2009 ASEE Annual Conference and Exposition, June 14, 2009 - June 17, 2009.

Ohland, M. W., S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, 2008, Persistence, engagement, and migration in engineering programs: Journal of Engineering Education, v. 97, p. 259-278.

Osborne, J., and B. Jones, 2011, Identification with Academics and Motivation to Achieve in School: How the Structure of the Self Influences Academic Outcomes: Educational Psychology Review, v. 23, p. 131-158.

Osipow, S. H., and L. F. Fitzgerald, 1995, Theories of Career Development: Needham Heights, MA, 353 p.

Pascarella, E. T., and P. T. Terenzini, 1979, Interaction Effects in Spady's and Tinto's Conceptual Models of College Dropout: Sociology of education, v. 52, p. 197-210.

Pascarella, E. T., and P. T. Terenzini, 1980, Predicting Freshman Persistence and Voluntary Dropout Decisions from a Theoretical Model: The Journal of higher education, v. 51, p. 60-75.

Pierson, R. R., 1962, Changes of Majors by University Students: Personnel and Guidance Journal, v. 40, p. 458-461.

Pike, G., 1991, The Effects of Background, Coursework, and Involvement on Students' Grades and Satisfaction: Research in Higher Education, v. 32, p. 15-30.

Pike, G. R., 2003, The relationship between institutional mission and students' involvement and educational outcomes: Research in Higher Education, v. 44, p. 241-261.

Porter, S. R., 2006, Institutional structures and student engagement: Research in Higher Education, v. 47, p. 521-558.

Porter, S. R., and P. D. Umbach, 2006, College Major Choice: An Analysis of Person-Environment Fit: Research in Higher Education, v. 47, p. 429-449.

Prediger, D., 1982, Dimensions Underlying Holland's Hexagon: Missing Link Between Interests and Occupations?: Journal of Vocational Behavior, v. 21, p. 259-287.

Raudenbush, S. W., and A. S. Bryk, 2001, Hierarchical Linear Models: Applications and Data Analysis Methods Thousand Oaks, California, Sage Publications.

Reyna, R., T. Reindl, K. Witham, J. Stanley, and C. f. B. P. National Governors Association, 2010, Complete to Compete: Common College Completion Metrics. Technical Guide, NGA Center for Best Practices.

Ricco, G., N. Salzman, R. Long, and M. Ohland, 2012, Sectionality or Why Section Determines Grades: an Exploration of Engineering Core Course Section Grades using a Hierarchical Linear Model and the Multiple-Institution Database for Investigating Engineering Longitudinal Development: American Society for Engineering Education Annual Conference.

Robinson, R. A., 2004, Pathways to completion: patterns of progression through university degree: Higher Education, v. 47, p. 1-20.

Robinson, R. A., and L. J. Bornholt, 2007, Pathways theory of progression through higher education: Australian Journal of Educational and Developmental Psychology, v. 7, p. 49-62.

Roe, A., and R. Baruch, 1967, Occupational changes in the adult years: Personnel Administration, v. 30, p. 26-32.

Seymour, E., 1995, The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account: Science Education, v. 79, p. 437-473.

Smith, M. A., and R. W. Baker, 1987, Freshman Decidedness Regarding Academic Major and Adjustment to College: Psychological Reports, v. 61, p. 847-853.

Spady, W., 1970, Dropouts from higher education: An interdisciplinary review and synthesis: Interchange, v. 1, p. 64-85.

State Higher Education Executive Officers (SHEEO), 2005, Accountability for Better Results – A National Imperative for Higher Education.

Steele, G. E., G. J. Kennedy, and V. N. Gordon, 1993, THE RETENTION OF MAJOR CHANGERS - A LONGITUDINAL-STUDY: Journal of College Student Development, v. 34, p. 58-62.

Stevens, R., Daniel M. Amos, Lari Garrison, and Andy Jocuns, 2007, Engineering as Lifestyle and a Meritocracy of Difficulty: Two Pervasive Beliefs Among Engineering Students and Their Possible Effects.: Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, Hawaii, June 24-27, 2007.

Stevens, R., K. O'Connor, L. Garrison, A. Jocuns, and D. M. Amos, 2008, Becoming an Engineer: Toward a Three Dimensional View of Engineering Learning: Journal of Engineering Education, v. 97, p. 355-368.

Suresh, R., 2007, The Relationship between Barrier Courses and Persistence in Engineering: Journal of college student retention, v. 8, p. 215-239.

Szafran, R. F., 2001, The effect of academic load on success for new college students: Is lighter better?: Research in Higher Education, v. 42, p. 27-50.

Tansley, D. P., L. M. Jome, R. F. Haase, and M. P. Martens, 2007, The effects of message framing on college students' career decision making: Journal of Career Assessment, v. 15, p. 301-316.

Theophilides, C., P. T. Terenzini, and W. Lorang, 1984, Freshman and sophomore experiences and changes in major field: The Review of Higher Education, v. 7, p. 261-278.

Tinto, V., 1988, Stages of Student Departure - Reflections on the Longitudinal Character of Student Leaving: Journal of Higher Education, v. 59, p. 438-455.

Titley, R. W., B. Titley, and W. M. Wolff, 1976, Major Changers - Continuity of Discontinuity in Career Decision-Process: Journal of Vocational Behavior, v. 8, p. 105-111.

Titley, R. W., and B. S. Titley, 1980, Initial Choice of College Major - Are Only the Undecided Undecided?: Journal of College Student Development, v. 21, p. 293-298.

Titley, R. W., and B. S. Titley, 1985, Initial Choice of College Major and Attrition - The Decided and Undecided After 6 Years: Journal of College Student Development, v. 26, p. 465-466.

Trow, M., 1973, Problems in the Transition from Elite to Mass Higher Education, Berkeley, CA, Carnegie Commission on Higher Education, p. 57.

van der Hulst, M., and E. Jansen, 2002, Effects of curriculum organisation on study progress in engineering studies: Higher Education, v. 43, p. 489-506.

Vogt, C. M., 2008, Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs: Journal of Engineering Education, v. 97, p. 27-36.

Vogt, C. M., D. Hocevar, and L. S. Hagedorn, 2007, A Social Cognitive Construct Validation: Determining Women's and Men's Success in Engineering Programs: The Journal of higher education, v. 78, p. 337-364.

Volkwein, J. F., and W. G. Lorang, 1996, Characteristics of Extenders: Full-Time Students Who Take Light Credit Loads and Graduate in More than Four Years: Research in Higher Education, v. 37, p. 43-68.

Vonnegut, K., 1981, Palm Sunday: New York City, Delacorte Press.

Warren, J. R., 1961, Self concept, occupational role expectation, and change in college major: Journal of Counseling Psychology, v. 8, p. 164-169.

Wessel, J., A. Ryan, and F. Oswald, 2008, The Relationship between Objective and Perceived Fit with Academic Major, Adaptability, and Major-Related Outcomes: Journal of Vocational Behavior, v. 72, p. 363-376.

Whitt, E. J., M. I. Edison, E. T. Pascarella, A. Nora, and P. T. Terenzini, 1999, Women's perceptions of a "chilly climate" and cognitive outcomes in college: Additional evidence: Journal of College Student Development, v. 40, p. 163-177.

Willcoxson, L., 2010, Factors affecting intention to leave in the first, second and third year of university studies: a semester-by-semester investigation: Higher Education Research & Development, v. 29, p. 623-639.

Willcoxson, L., and M. Wynder, 2010, The relationship between choice of major and career, experience of university and attrition: Australian Journal of Education, v. 54, p. 175-189.

Zhongjun, C., and G. Roger, 2006, Student attrition at a new generation university in Australia, Australian Association for Research in Education Conference 2006, Adelaide.

APPENDIX

APPENDIX. TABLE

Table 1. Example authors and databases with descriptions of their change of major methodology.

Paper	Sample	Number of Schools	Major change and selection methodology	Sample Skew	Longitudinal
MIDFIELD	871742	10	From registrar	All students	Y
Allen	50000	25	From registrar	ACT takers only	N
Beggs	852	1	From registrar	All students	N
Warren	525	200	From registrar. Divided major changers into "no change," "minor change," and "major change.	National Merit Finalists	N
Brown	179	1	From registrar	Freshmen only	N
Smith	60	1	From registrar	Freshmen only	N
Molnar	904	1	From registrar	Freshmen only	N
Gordon	110	1	Theophilides (early, late, constant) metric	Alternative advising program	Y (four year follow up)
Elliot	80	1	Grouped by sets of major changes	College of Human Development	N
George-Jackson	16850	5	Four non-standard categories	Only graduates	Y (major change follow up)
Titley (1980)	684	1	From registrar and self reported	Only freshmen	Y (two year follow up)
Titley (1985)	684	1	From registrar and self reported	Only freshmen	Y (two year follow up)
Pierson	2369	1	From registrar and self reported	Only graduates	N
Harris	19	1	From registrar	Only undecided in advising workshop	Y (one semester follow up)
Steele	618	1	From registrar	Alternative advising program	Y (graduation/attrition follow up)
Lewallen	27064	433	From registrar	Only undecided students who graduated or persisted to eight semesters	Y
Kramer	13417	1	From registrar	Only graduates	Y
Micceri	6271	1	From registrar	All students	Y
Krupka	14000	1	From registrar	Only freshmen and sophomores	N
Lam	4403	1	From registrar	Only graduates	Y
Knight	2585	1	From registrar	All students	Y
Kreysa	438	1	From registrar	FTIC	Y
Theophilides	1360	1	Theophilides (early, late, constant) metric and self reported	Only freshmen and sophomores	N

VITA

VITA

George Dante Ricco was born in Kent, Ohio, a number of years ago. He attended Walsh Jesuit High School against his own will, and instead of becoming a Jesuit, he decided to go to Case Western Reserve University in Cleveland to obtain his B.S.E. in engineering physics in 2002. He then spent a number of years on the beach at the University of California at Santa Cruz, receiving degrees in Physics (2007) and Earth and Planetary Sciences (2008) until emancipated by Prof. Matthew Ohland at Purdue University. He enjoys cycling, weightlifting, running, photography, volunteering at a number of organizations, and the untold intellectual pleasures provided by the study of Lagomorph physiology. He resides in Lafayette, Indiana, and in-between job interviews he spends time with his Leporidae life partner, Rochelle Huffington Nibblesworth.