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Examining the Influence of Engineering Students' Course Grades on Major Choice and Major Switching Behavior*

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The need for science and engineering workers has raised concerns regarding the persistence of undergraduate students in engineering. Since academic institutions ordinarily provide students with feedback on course performance through grades, understanding the role of course grades in influencing student major choice and major switching behavior is critical. This research identifies factors associated with switching majors within engineering, as well as examines how students' expectations regarding future grades may influence major choice. The data include individual-level demographic characteristics and detailed transcript records from 27,065 students in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). Logit regression analysis on the likelihood of switching majors indicate that students who initially declare industrial or mechanical engineering are less likely than those who declare electrical to switch majors. Scores on the Scholastic Aptitude Tests (SATs), as well as introductory course grades in Calculus and Physics are associated with the likelihood of changing majors. Findings from the propensity score analysis show that students with higher grade point averages in introductory courses are more likely to stay in their intended engineering major if they expect to receive relatively higher grades in their intended major's upper-division courses. Research findings have broad implications for academic institutions and how grading distributions and practices may be associated with students' switching behavior and major choice in engineering.

Keywords: course grades; major choice; switching; persistence

1. Introduction

Concerns regarding the retention rate of undergraduate engineering majors abound, particularly in light of the continued demand for a highly skilled and diverse scientific and technological workforce. The U.S. Bureau of Labor Statistics estimates that engineering occupations will increase by 11.3% between 2008 and 2018, compared to all occupations, which will increase by 10.1% [1]. To meet this growing need for engineering professionals, it is critical for higher education institutions to find ways to improve the retention of engineering majors. Among students who matriculated in a 4-year college or university in 2003 and declared engineering as an initial major, only 55.9% graduated in engineering as of 2009. Meanwhile, 22.3% migrated into non-science and non-engineering fields, 10.1% into physical, math, and computer sciences, 2.7% into agricultural and biological sciences, and 3.5% into social and behavioral sciences [1]. While it is common for students in the United States to transfer between fields as they progress through their undergraduate studies, a disproportionately lower number of students transfer into engineering from non-engineering disciplines [2]. Thus, the outflow of students from engineering with limited inflow of students from other fields contributes to the lower number of students completing engineering degrees. The migration and persistence patterns of science and engineering students have therefore inspired a body of research identifying precipitating factors, such as poor academic preparation, "chilly engineering climate," difficult course material, poor instruction and advising, and variations in student self-confidence [3–6]. An integral component of evaluation and assessment in undergraduate studies, course letter grades and grading distributions across academic fields have also received increasing attention as a potential source of variation in student persistence and major choice behavior [7–13]. We therefore focus on course letter grades to further understand student major choice and major switching (migration) patterns.

To identify the role of grades in major choice and major switching behavior, we addressed the following two research questions: *What are the indicators for switching behavior among students who complete an engineering degree? Are students more likely to select a major if they expect to receive higher grades in that major's upper division courses relative to other*

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engineering majors? Our research findings identify the influence of grading practices on engineering student major choice. Additionally, our findings contribute to the conversation regarding whether standardizing grading distributions across majors could reduce the number of students migrating out of engineering. We propose that changes such as providing students with more information regarding course-specific and/or discipline-specific grading distributions may be a more tangible solution to addressing issues associated with imagined differences in grading distributions across disciplines. Providing students with context for grades may enable them to more accurately assess their own performance when making major choice decisions.

2. Background

The prevailing concern regarding course letter grades arises from the differential grading distributions that may exist between science and non-science majors at higher education institutions [7]. Studies in this vein generally tend to conclude that stricter grading standards that may be more prevalent in science and engineering fields compared to humanities and social science fields are a disincentive for persistence. As Rask puts forward, "if STEM [Science, Technology, Engineering, and Mathematics] departments grade lower than non-STEM departments, and the grade received is an important factor in the major decision, grading practices could be an important factor in the high attrition rates experienced in STEM majors" [8]. Rask shows that the absolute grade received is an important predictor of the likelihood of taking another course in the major the subsequent semester. Additionally, Ost suggests that students are "'pulled away' by their high grades in non-science courses and 'pushed out' by their low grades in their [science courses]" [9].

Yet, the relationship between grading distributions, individual student grades, and major choice is more complex. For example, when student effort and motivation are taken into account in a regression-discontinuity approach, letter grades are not necessarily predictive of student major persistence [10]. Additionally, the effects of letter grades can vary by student gender and the type of outcome studied. Owen [11], as well as Rask and Tiefenthaler [12] find that women are more responsive to letter grades than men in major selection, whereas Main and Ost [13] do not find similar effects. Since the effects of letter grades can vary depending on context and outcome studied, we investigate the complexity of the influence of letter grades on major choice specifically on students who matriculated in engineering. Identifying the relationships between course grades and major choice extends previous literature examining factors influencing major choice. For example, Ngambeki, et al. found that thing orientation is a predictor of engineering major interest using the person-thing orientation construct [14], whereas Martin, et al. determined that parental education plays a role in student academic choice [15]. Meanwhile, Yuen et al. identified several reasons why students decided to major in engineering including personal and career interests, perceived aptitude, and the ability and potential to improve society [16].

3. Theoretical framework

Albert Bandura's social cognitive theory of self-regulation is applied to contextualize our examination of the role of course grades and intentions in student major choice [17–18]. Bandura proposes that through self-regulatory systems, in particular the self-monitoring sub-function, individuals regulate their motivation and actions through feedback regarding their performance. A critical element is the individual's generation of social referential comparisons—in effect, individuals consider their performance using multiple sources of information, including a comparison of their performance against the performance of others and the environmental standards. There is evidence that measuring oneself in comparison to others is particularly important among engineering students [19]. Thus, we consider student's performance in introductory courses, as well as their peers' performance in the same courses, in our analyses. Additionally, since purposeful action is regulated and guided by forethought, we consider students' initial major intentions.

4. Data

Empirical data come from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), and include individual-level demographic characteristics and detailed transcript records [20]. The demographic variables comprise student gender, race/ethnicity, citizenship, age at enrollment, year of entry, Scholastic Aptitude Test (SAT) scores, and initial and early major intentions. Course-related variables of interest include students' letter grades in introductory and upper-division engineering courses, as well as the proportion of "A's" and "C-'s" and below awarded in upper division courses for each engineering discipline by year. The dataset is composed of 14 entering cohorts from 1990 through 2003 across 9 large, public four-year institutions primarily located in the southeastern United States. Although there

Table 1. Demographic Characteristics of Studentst

Variable	Proportion
Female	0.225
Asian/Asian-American	0.065
Black/African-American	0.108
Hispanic/Latino	0.025
Native American	0.002
White	0.694
International	0.072
	Mean
SAT Math	549
SAT Verbal	479

are 11 institutions in the MIDFIELD dataset, two were omitted because they did not offer all five of the engineering disciplines that we selected for analysis. These institutions represent approximately 10% of the engineering graduates across the Unites States annually. The breadth of the MIDFIELD data thus allows for a comprehensive examination of patterns in student major choice.

Although MIDFIELD includes data from students across all majors, we limit our sample to students who likely have similar levels of motivation and interest in completing a bachelor's degree in engineering to more plausibly isolate the effect of letter grades on engineering students. Therefore, we only include students who matriculated and graduated in engineering within six years. We limit our sample to the five largest engineering majors in the MIDFIELD dataset: Chemical, Civil, Electrical, Industrial, and Mechanical. We also restrict our study to first-time undergraduate students who complete a degree in the same institution where they matriculate. Therefore, students who transfer from another institution and students who leave the undergraduate program are not included.

The sample includes records of 27,065 students. Of the sample, approximately 23% are female, 69% are White, and 7% are International students (Table 1). Nearly 60% of the students are enrolled in a first-year engineering program and are not required to declare a major intention upon entry (Table 2). Among those who declared a major intention by the first semester, a greater proportion indicated electrical or mechanical engineering. In descending order, the largest number of students in the sample graduated in mechanical, electrical, civil, industrial, and chemical engineering.

There is variation in the distribution of grades in upper division courses across majors and time. Overall, however, among the majors included in this study, mechanical engineering assigns the fewest A's (Table 3). In mechanical engineering, about 23% of the grades assigned are A's compared to industrial engineering where 33% of the grades in upper division courses are A's. Electrical and mechanical engineering assign more grades below C- (~8%) compared to industrial, chemical, and civil engineering (~5%). While these statistics provide an overview of the distribution of upper division grades across majors, these types of statistics do not necessarily indicate which majors are more "difficult" or have stricter grading standards. It is

Table 2. Student Major at Matriculation and Graduation

	Major at Matriculation		**Major at Graduation**	
	Freq	**Percent**	**Freq**	**Percent**
Electrical	3,109	11.49	6,077	22.45
Mechanical	2,794	10.32	7,469	27.60
Chemical	2,269	8.38	4,104	15.16
Civil	1,648	6.09	5,118	18.91
Industrial	1,304	4.82	4,297	15.88
First-Year Engineering*	15,941	58.90		
Number of Students	*27,065**			

* Sample includes only students who graduate in mechanical, electrical, civil, chemical, and industrial engineering.

Table 3. Course Grades Awarded in Upper-Division Courses by Major, (1990–2003)

	Proportion of A's	**Proportion Below C-**
Mechanical	0.227	0.081
Electrical	0.258	0.084
Civil	0.269	0.052
Chemical	0.290	0.055
Industrial	0.330	0.056
Number of Students	27,065	

not possible to distinguish between whether there are fewer A's due to instructors' grading standards or due to student effort.

5. Methods and Results

5.1 What are the indicators for switching behavior?

By limiting the sample to students who matriculate and graduate in engineering, we compare students who are more likely to have similar levels of motivation and interest in pursuing engineering to estimate the effect of letter grades on major choice. In this analysis, we use a subset of the sample including only students who declared a major in engineering upon entry or within the first semester of study. Students enrolled in institutions with first-year engineering programs are not included. The resulting sample includes 11,098 individuals who matriculated and graduated in engineering. Approximately 18% of these students switched between the five engineering majors during their undergraduate years. The referent group for the analysis includes students who declared electrical engineering at matriculation since this is the largest group who declared an intention.

Compared to students who declared an intention to major in electrical engineering, students who declared an intention to major in chemical engineering are more likely to switch majors. All else held constant, students who declared an intent to major in chemical engineering are 3.1 percentage points more likely to switch to a different major compared to students who declared an intent to major in electrical engineering (Table 4). Meanwhile, students who initially declared industrial and mechanical engineering are less likely to switch majors compared to students who initially declared electrical engineering. Therefore, there is a difference in probability of switching majors based on a student's initial intended major.

Holding everything else constant, students with higher SAT math scores are more likely to switch majors, whereas students with higher SAT verbal scores are less likely to switch majors. Introductory math and science courses taken during the first two years of study also influence the likelihood that a student will switch majors. The introductory course grades are measured on a scale of 0.0 to 4.0 where 4.0 is equivalent to an "A." All else held constant, a 1.0 increase in the Calculus II course letter grade leads to a 1.3 percentage point decrease in the likelihood of switching majors. The effect of the Physics I course letter grade is similar. An increase of 1.0 in the Physics II letter grade, however, decreases the likelihood of switching majors by 3.2 percentage points, everything else held constant.

5.2 Are students more likely to select a major if they expect to receive relatively higher grades in the major's upper-division courses?

Previous research has tended to focus on the actual letter grade received in determining student major choice. We apply propensity scores to examine

Table 4. Probability of switching majors (marginal effects)

Variable	**Coeff**	**Std. Err.**
Intended Major		
Industrial	**–0.121***	0.015
Mechanical	**–0.037***	0.010
Civil	–0.010	0.011
Chemical	**0.031***	0.010
Female	0.010	0.009
Asian	–0.019	0.014
Black	–0.013	0.013
Hispanic	–0.015	0.019
Native Am	0.049	0.062
International	–0.034	0.024
SAT Math	**0.012***	0.000
SAT Verbal	**–0.020***	0.000
High school GPA	–0.012	0.008
Calculus I	–0.005	0.005
Calculus II	**–0.013***	0.005
Chemistry I	–0.006	0.005
Chemistry II	–0.002	0.006
Physics I	**–0.012***	0.005
Physics II	**–0.032***	0.005
Obs	11,098	

* $p < 0.05$.
Note: Institution, Cohort, Missing Dummy Variables not shown.
Omitted category for intended major is Electrical.
Sample limited to students who indicated a major at matriculation.
(First-year engineering programs not included).

Table 5. Likelihood of staying in intended major if the predicted gpa is highest in intended major

	GPA greater than 3.6 intro courses	GPA between 3.0 and 3.6 in intro courses	GPA less than 3.0 in intro courses
	Coeff/Std Err.	Coeff/Std Err.	Coeff/Std Err.
Predicted GPA highest in intended major	0.199*	0.139*	–0.032*
	0.019	0.018	0.013
Observations	2,334	2,774	6,016

* $p < 0.05$.

whether students select majors based on their expected (predicted) future grades while taking into account students' initial or early major intentions. Our view is that students' decisions are based on the context of grade-related factors, including their own assessment of their expected performance in subsequent discipline-specific courses. While previous studies using observational data without information on motivation and effort in a regression framework are unable to distinguish whether letter grades or different levels of motivation influence student migration pattern, propensity score analysis allows for causal inference. Since students are more likely to select leniently graded courses when grade information is provided [21], are students also more likely to select a major when they *expect* that they will receive relatively higher grades in that major? Conditional on major intentions and assuming that students gather data on grade distributions from various informal sources, we estimate the impact of expected performance on student major selection using logit regression.

Expected performance is calculated using exact matching on gender and propensity score matching on race/ethnicity, SAT scores, high school grade-point average, percentage of students enrolled in the free lunch program at the student's high school, college institution, year of college matriculation, and letter grades earned in general undergraduate introductory courses in mathematics, chemistry, and physics. The expected performance variable predicts, given a student's background and introductory grades, how a student will perform in a major's upper division courses based on how other students with similar characteristics have performed in that particular major. For each student, we calculated the expected performance for each of the following majors: Chemical, Civil, Electrical, Industrial, and Mechanical Engineering.

Although we expect that students will be more likely to stay in their intended major when they expect to receive relatively higher grades in that major compared to other majors, we find that the likelihood of staying varies across students by introductory course grade point average. Among students who have a GPA of 3.6 or higher from introductory and prerequisite courses (mathematics, physics, etc.), students are 19 percentage points more likely to stay in their intended major if they expect their GPA to be highest in that major (Table 5) than if their GPA would be higher in another major. The effect is similar among students with a GPA between 3.0 and 3.6 in introductory courses, although to a smaller degree at 14 percentage points. Interestingly, students with a GPA lower than 3.0 in introductory courses are less likely to stay in their intended major where they are expected to have earned the highest GPA. While there are multiple potential factors that students use to identify their major, this finding suggests that students with lower introductory GPAs may not be weighing or factoring grades in their decision-making similarly to the students with relatively higher GPAs. They may place less weight to their overall or final GPA when selecting a major—they may be less likely to maximize their overall GPA. Other factors may play a larger role, such as employment prospects, affinity for a major, major requirements or entrance considerations, and social and cultural differences across the engineering disciplines.

6. Discussion

Our findings indicate that expected grades and previous performance (measured through introductory course grades) play an important role in student decision-making related to switching majors. Consistent with Bandura's social cognitive theory of self-regulation where individuals are guided to an extent by "referential comparisons"—evaluating their "performances in relation to the attainment of others" [17, p. 254], we find that students who have higher grade point averages are more likely to stay in their intended majors. It may be that in their self-evaluation in comparison to their reference group, they have confirmed a measure of adequacy that confirms their major intentions. This finding is also compatible with Ajzen's theory of planned behavior [22], where behavior is predicted from the alignment between intention and perceived behavior control over the action—students who have higher grade point averages may also have higher perceived control over their major selection and therefore continue in their intended major. Meanwhile, students with lower introductory course grade point averages are more likely to switch majors, in some instances, changing to majors where they may not be maximizing their overall grade point averages. From Bandura's theory, this behavior may stem from the "fidelity, consistency, and temporal proximity of self-monitoring," such that the performance feedback from introductory course grades may not be as informative or as important to members of this group. It may also be that members of this group may be making decisions based on other factors beyond maximizing grade point averages.

Whether the grades students earn in the upper level courses in the different engineering disciplines are the result of differences in faculty expectations or differences in student performance, the patterns above create expectations that become a part of each discipline's culture. Leonardi, Jackson, and Diwan found that "ranking oneself against others" is a practice of engineering students [19, p. 408]. In particular, they found that grades are the measure of comparison—91 percent of informants in that study referred to grades before they were prompted to do so, most in the context of comparing their grades to those of others. While some of the justification for the cultural norms of engineering come from well-established stereotypes [23], the findings of Leonardi, Jackson, and Diwan found conditions favoring cultural reproduction—the incidence of ranking oneself against others (and other practices) increases with tenure in the engineering program, establishing this practice as a cultural norm to which newcomers believe they must adapt [19]. Notably, the expected grade of the informant was not related to the incidence of this practice—engineering students rank themselves against others regardless of their relative rank in the class. While the informants in the study by Leonardi, Jackson, and Diwan included only software and computer engineering students, earlier work by Stevens, Amos, Jocuns, and Garrison that found engineering to be a meritocracy of difficulty suggests that students of other engineering disciplines are likely to have similar cultural norms [24]. Therefore, if the cultural expectations regarding grades are established at the level of individual engineering disciplines, engineering students are likely to assess their fit with a particular major by comparison to the grades of other students in that major. Students whose grades are below those typically earned by students in a particular discipline would be demotivated by unfavorable social comparisons [18], and tend to switch to a major where they perceive that they would fit better—a discipline where their grades would be "typical" or better.

At the two extremes, students are 15 percentage points more likely to switch from Chemical Engineering than from Industrial Engineering. These two disciplines are similar in that they both have a high fraction of women, but previous studies have shown that these disciplines are culturally different from one another. In a study of women in Industrial Engineering by Brawner et al. [25], women seemed to remain in the discipline because of the environment. However, Brawner et al. [26] also found that women in Chemical Engineering remain in the discipline in spite of the environment. Many reasons that students give for staying in the discipline are common to the two disciplines, including career opportunities, flexibility, and relationships with others in the discipline. Nevertheless, Industrial Engineering students were more likely to describe their discipline passionately—claiming to "love" the major, whereas Chemical Engineering students tend to speak about "sticking it out" or "proving that they can make it." Further, other researchers have described Industrial Engineering as "inviteful" [27]. While the culture of engineering disciplines is multifaceted, it seems likely based on these earlier studies that grade expectations are an important part of that culture and that part of what makes Industrial Engineering attractive is that students have an expectation that they are more likely to earn higher grades in that major [25].

Our work notes that Mechanical Engineering and Electrical Engineering have similar grade distributions, and other studies [28–29] show that they have similar fractions of women. So while the grade distributions of these two disciplines can explain why students are more likely to switch from these disciplines than from Industrial Engineering, other factors must explain why students are more likely to switch from Electrical Engineering than from Mechanical Engineering. Studying several engineering disciplines in a single institution in New Zealand, Godfrey describes students of Electrical Engineering as "narrowly focused, clever, but physically unprepossessing. . . with an almost obsessive interest in computers" [30]. This narrower cultural milieu may explain some of the higher switching behavior from Electrical Engineering. Orr, Lord, Layton, and Ohland found that almost half of all Mechanical Engineering graduates start in other disciplines [28]. While they only hypothesize as to the reasons for the discipline's ability to attract switchers, it is possible that the same influences would make students who start in Mechanical Engineering less likely to switch out of that discipline.

In regard to the findings related to SAT scores, SAT math scores are one of the best predictors of grades in engineering [31], so it might be that students with higher SAT math scores are more likely to switch majors because they can do so with relative ease—they are less likely to face barriers if they choose to switch majors. The finding that students with higher SAT verbal scores are *less* likely to switch majors may be a consequence of the population studied. Zhang and colleagues found that engineering students with the highest verbal scores on the SAT are more likely to leave engineering perhaps because their talents are not being nurtured based on the way engineering has traditionally been taught [31]. As a result, students with higher verbal scores are less likely to be among the engineering graduates who are considered in this study—there is less variability due to the restriction of range of the population meeting our study criteria. This hypothesis is supported to some extent by the lower standard deviation of SAT verbal scores. If higher SAT math scores are related to lower barriers to switching, we should expect that higher grades in foundational engineering courses would have the same effect, but they do not. Higher grades in Calculus II, Physics I, and Physics II decrease the likelihood of switching majors. Based on Godfrey's discussion of how mathematics is used differently in different disciplines [30], it may be that the students who do well in Calculus II are predisposed to select (and not switch from) the majors that make good use of those talents. Similarly, Physics I (mechanics) and Physics II (electricity and magnetism) tend to appeal to students of certain disciplines.

While our findings are consistent with Bandura's social cognitive theory and previous research provides context for explaining some of the behavior we document, our research does not identify the mechanisms for students' major persistence and switching behavior. Further, while our data include several cohorts of engineering students across multiple institutions, we only analyze data from students who have already indicated a major at matriculation and who eventually complete an engineering degree in one of the five largest disciplines: Chemical, Civil, Electrical, Industrial, and Mechanical. Although this approach yields a sample that is more similar in terms of several relevant characteristics, it limits the generalizability of the findings. For example, our findings do not offer insight into students who are undecided about their engineering major interests at the time of matriculation. Insofar as students who are undecided about their major at matriculation or who do not eventually complete an engineering degree are sensitive to letter grades, it may be that the effects of letter grades are underestimated. Nevertheless, our findings provide evidence of the importance of letter grades and students' relative rank within grading distributions in major persistence.

Importantly, this work also raises many questions that might be addressed in future research. If student grades in foundational courses influence student major switching behaviors, to what extent do student experiences in those courses influence their disciplinary choices in the first place? To what extent are faculty members reinforcing the tendency for students to rank themselves relative to other students by posting grade distributions and by the use of norm-referenced grading practices? Would the strategic deployment of criterion-referenced grading practices result in a cultural shift in engineering and how might such a cultural shift make engineering "inviteful" to a more demographically diverse student body?

7. Conclusion

We examined the role of letter grades, student major intentions, and grade expectations in engineering students' major switching behavior. Based on our logit regresion analysis, we found that compared to students who initially declare electrical engineering, students who initially declare industrial or mechanical engineering are less likely to switch majors. SAT scores and grades from college-level introductory courses in Calculus and Physics are associated with students' likelihood of switching majors. Based on our propensity score analysis, we found that students with higher overall grade point averages from introductory courses (e.g., Calculus, Physics, Chemistry) are more likely to stay in their initital intended engineering major, particularly if they expect to continue to receive relatively high grades in that major's upper-division courses. These research findings have important implications for academic institutions and how grading distributions and practices may be associated with students' switching behavior and major choice in engineering. Many academic institutions, for example, Cornell University [32] and Princeton University [33] have examined their own institutions' grading distributions and policies. Therefore, academic administrators, faculty, and other key stakeholders can use these findings to help inform discussions regarding grading policies and how letter grades and distributions may influence their students' major selection and persistence behavior.

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