Working Title: Career Plans of Undergraduate Engineering Students: Characteristics and Contexts

Gilmartin, S.K., Antonio, A.L., Chen, H.L., Brunhaver, S.B., Sheppard, S.D.

Each year some 70,000 students graduate from one of over 350 universities and colleges in the U.S. with a Bachelors of Science (B.S.) in engineering (National Science Foundation, 2011). *How many of these graduates see this degree as leading to engineering work? Are there particular types of engineering students who are more likely to go into engineering work? Are there educational experiences or environments that influence whether engineering students choose to enter the profession?* Answers to these questions inform our understanding of the engineering workforce by illustrating how the individual, societal, and financial investment in engineering education translates into practicing engineers, and the extent to which increased diversity in engineering student ranks results in a more diverse engineering labor market.

This chapter begins to address these questions by building on recent findings from the Academic Pathways of People Learning Engineering Survey (APPLES) (Sheppard et al., 2010), which is a part of the NSF-funded Academic Pathways Study.[1] In this work, we examined the post-graduation plans of seniors at 21 engineering schools across the U.S., and identified several predictors of plans to pursue engineering jobs after college. Positive predictors included financial motivation to study engineering (i.e., seeing engineering as a means to a job, reporting that "engineers are well-paid"), psychological motivation to study engineering (i.e., being intrinsically interested in engineering, reporting that engineering is "fun"), exposure to the engineering profession as interns or employees, and involvement in engineering courses. Negative predictors included confidence in professional and interpersonal skills and extracurricular involvement in non-engineering activities. We also examined students' plans to pursue non-engineering jobs, engineering graduate school, and non-engineering graduate school. Across all models, confidence in professional/interpersonal skills consistently characterized students who were leaning away from engineering options and towards non-engineering options, while psychological motivation to study engineering consistently characterized students who were leaning towards engineering options and away from non-engineering options.

The current work extends the APPLES findings both conceptually and methodologically. First, we examine how focused engineering students are in their post-graduation plans. Are students considering engineering options exclusively? Are they considering non-engineering options exclusively? Or do their post-graduation plans include engineering and non-engineering pursuits? Second, we examine how individual socioeconomic characteristics, major field of study, institutional selectivity and resources, and the engineering labor market help to explain variation in post-graduation plans. Are there consistent differences in plans by major and/or by institutional type? How do the median engineering salaries in the states in which students are

[1] The Center for the Advancement of Engineering Education (CAEE) was established by the NSF in 2002 and consisted of three research elements: Scholarship on Learning Engineering, Scholarship on Teaching Engineering, and the Institute for Scholarship on Engineering Education. CAEE's five partner institutions were Colorado School of Mines, Howard University, Stanford University, University of Minnesota, and University of Washington, the lead institution. The Academic Pathways Study was a major undertaking of CAEE's Scholarship on Learning component (Clark et al., 2008).

located tie into students' perceptions of their engineering (or non-engineering) futures? We draw from three national data sources (in addition to APPLES) to explore the constellation of plans, socioeconomics, majors, institutions, and labor markets, and employ multilevel modeling techniques to consider the effects of individual- and institution-level measures simultaneously. For these analyses, we examine plans among both junior and senior engineering students, rather than seniors alone, at our 21 schools.

Situating this research more broadly in the field, the current work contributes to thinking about the Engineering Career Pathway (ECP).[2] Much of the research on the ECP has been focused on the factors influencing persistence and retention in undergraduate engineering programs. A variety of methods have been employed, including longitudinal approaches (e.g., Brainard and Carlin, 1998; Eris et al., 2005, 2007, 2010; Huang, Taddese, and Walter, 2000), cross-sectional surveys such as APPLES and the Pittsburgh Freshman Engineering Attitudes Survey (Besterfield-Sacre et al., 1997, 2001), and qualitative interviews (Seymour and Hewitt, 1994, 1997). Seymour and Hewitt's three-year study of enrollment patterns and interviews with over 300 juniors and seniors at seven institutions serves as the foundational work in research on persistence in science and engineering education. Seymour and Hewitt found little difference in the academic preparation or performance of students who switched from science, math, or engineering (SME) majors to non-SME majors ("switchers") and those who persisted in earning SME degrees ("non-switchers"). However, those who did decide to switch often cited a loss of interest in SME subjects, a belief that non-SME majors would be more interesting or offer a better education, poor teaching by SME faculty, and perceptions of academic overload within the SME curriculum. Notably, these concerns were shared by the non-switchers who chose to continue with the SME major.

The use of academic transcripts as a source of data about engineering pathways was first established in Adelman's (1998) analyses of engineering students' college transcripts in the High School and Beyond/Sophomore Cohort Longitudinal Study (1982-1993). More recently, Ohland et al. (2008, 2009, 2011) and Lord et al. (2008, 2009) have expanded upon this method with analyses of the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) dataset, which is comprised of academic records for over 75,000 first-time-in-college students matriculating in engineering from 1988 through 1998 across nine partner institutions. While prior research has found greater persistence in engineering majors among women than among men (Borrego, Padilla, Zhang, Ohland, and Anderson, 2005), Ohland et al. (2011) highlight a need to disaggregate persistence rates by not only gender, but underrepresented minority status and institution as well.

As noted by Ohland et al. (2011), a variety of outcomes have been used to analyze persistence in engineering fields among undergraduates. Traditionally, quantitative metrics of engineering success have included eighth semester enrollment and six-year graduation data. As proposed by Ohland et al., the work of Fenske, Porter, and DuBrock (2000) and Anderson and Kim (2006) suggest that looking at graduation rates and other metrics beyond the typical four years is critical for studies of engineering students, in order to more accurately capture trends among women and men and among students from different racial/ethnic sub-groups.

[2] The ECP is sometimes referred to as the "engineering pipeline" (Watson and Froyd, 2007).

The APPLES instrument uses self-reports of intention to major in engineering and estimated post-graduation plans as measures of persistence (Chen et al., 2008). In this study, we focus on the latter: post-graduation plans among declared, late-stage engineering majors. By examining how these plans intersect with a range of individual and environmental characteristics (e.g., socioeconomic background, major field of study, institutional selectivity), this work lengthens the view of engineering persistence established in previous literature, and adds a level of granularity that is essential to understanding which group(s) of students are more likely to enter the engineering workforce.

In the following sections, we describe the data and methods for the current work. Then we present findings from both descriptive analyses and multivariate models of post-graduation plans. We conclude the chapter with discussion of our results in the context of other ECP research, and consider implications for future work in this area.

METHODOLOGY

Data

The data for this study are drawn primarily from the APPLES survey, a 50-item instrument administered to over 4,000 students across 21 U.S. colleges and universities in 2008 (Donaldson et al., 2007, 2008). The APPLES instrument is one of the research tools developed and used by the NSF-funded Academic Pathways Study (APS). Details on the design of APS and its various instruments can be found in Clark et al. (2008), and overall findings are presented in the project's final report (Atman et al., 2010).

Institutions were recruited to participate in the APPLES study based on a stratified sampling plan designed to capture the broad range of four-year colleges and universities in the U.S. (Donaldson et al., 2008). The distribution of institutions by the 2000 Carnegie Classification (The Carnegie Foundation for the Advancement of Teaching, 2001) is listed in Appendix A. Institutions were geographically diverse, representing 17 states across major U.S. regions. The APPLES technical report (Sheppard et al., 2010) provides additional discussion of the representativeness of the institutional sample.

The sample for the present study is comprised of 2,143 survey respondents who marked that they were "juniors," "seniors," or "fifth-year seniors or more" across the 21 APPLES institutions. Respondents in each academic cohort were similar on key demographic measures and measures of engineering plans following graduation, thus allowing us to aggregate cohorts and consider predictors of plans across a larger student group. Notably, women, at 30.8 percent of the sample for this study, are overrepresented as compared with the U.S. population of students who have earned an engineering degree (see NSF, 2008). Sample statistics also indicate that (prospective) electrical engineering degree-earners are underrepresented and mechanical engineering degree-earners are overrepresented among APPLES senior respondents as compared with the national population.[3] Descriptive analyses are therefore conducted separately by gender and major where appropriate. Sheppard et al. (2010) provide further details about the

[3] "Prospective" because all APPLES senior respondents were still enrolled at their undergraduate institutions at the time of the study, and thus marked their major(s), not the field in which they earned their degree(s).

representativeness of the student respondent sample as compared with the national population of engineering undergraduates.

Three additional sources of data were merged into the APPLES survey dataset in order to analyze institutional and labor market effects. For measures of the labor market, median annual wage data by engineering field and U.S. state were obtained from the Bureau of Labor Statistics, National Cross-Industry Estimates, May 2006 (see BLS, 2007). For institutional selectivity, institutional resources, and related measures, data for each of the 21 APPLES institutions were obtained from the Integrated Postsecondary Education Data system (IPEDS), 2006 (see NCES, 2006), and the American Society for Engineering Education (ASEE) Engineering and Engineering Technology College Profiles, 2006 (see ASEE, 2006). For measures of selectivity (i.e., SAT percentile scores) at a small number of schools, 2007-2008 IPEDS data were used in the absence of such data for 2006-07; for the student-to-faculty ratio at each institution, 2008-09 IPEDS data were used in the absence of such data for 2006-07.

Methods

Due to the nested nature of the dataset—2,143 students within 21 institutions—hierarchical linear modeling (HLM) techniques were selected for multivariate modeling. Traditional ordinary least squares (OLS) regression techniques may underestimate standard errors in this type of sample, given the dependence of observations within each school; HLM accounts for such clustering by partitioning between-school variance and within-school variance, thereby generating more robust standard errors and allowing us to directly estimate school-level effects on outcomes (Raudenbush & Bryk, 2002). The primary outcome measures, which place respondents into one of three post-graduation plans categories, necessitate hierarchical generalized linear modeling (HGLM) techniques. We conducted multinomial logistic regression (MLR) analyses in HGLM for these measures. We report the results of all models separately for Level 1 (student-level measures) and Level 2 (institution-level measures holding all Level 1 variables constant).

Level 1 models

Level 1 analyses examined the relationships between students' post-graduation plans, background characteristics, educational experiences and attitudes, and education and employment contexts. In total, the conditional Level 1 model contains 18 independent variables.[4]

[4] The multinomial logistic model in a hierarchical generalized linear model is given by:

$\text{Prob}(R_{ij} = 1) = \phi_{1ij}$
$\text{Prob}(R_{ij} = 2) = \phi_{2ij}$
$\text{Prob}(R_{ij} = 3) = \phi_{3ij} = 1 - \phi_{1ij} - \phi_{2ij}$

Where each response category (R) is associated with a probability (ϕ). Using a multinomial logit link (logged ratio of probabilities), the Level 1 structural model is expressed as:

$\eta_{1ij} = \beta_{0j(1)}$ + [student background characteristics (2 measures) + educational experiences/attitudes (7 measures) + major (8 measures) + expected salary (1 measure) in the form $\sum \beta_{qj(1)} X_{qij}$]

Each independent variable was centered around its respective group mean. To facilitate interpretability and comparability of coefficients, all non-dichotomous variables were standardized prior to centering. Preliminary Level 1 models tested the effects of two variables, "Underrepresented Racial/Ethnic Minority (URM) Status" and "Gender," as separate, independent measures; final models tested "URM women" (versus all other students), given exploratory results (both descriptive and multivariate) suggesting that this group, as compared with their peers, had unique post-graduation plans (see also Sheppard et al., 2010).

In order to retain the maximum number of cases for our multivariate models, gender was imputed for 20 missing values using logistic regression techniques, and mean-replacement was used for missing values on other independent variables, including four composite measures (the proportion of missing values on any given variable ranged from <.5% to 2.5%). Independent variables are described in "Measures," below.

Level 2 models

IPEDS and ASEE measures reflecting institutional selectivity and resources were tested at Level 2. Given that there were only 21 institutions in the APPLES dataset, we were limited in the number of institutional variables that we could include in any one model. Preliminary analyses of simple correlations indicated how these institutional characteristics clustered into thematic groups and were related with dependent measures; these groups formed the basis of the subsequent testing sequence designed to account for the parameter limitations. Variables were modeled by thematic group, e.g., academic selectivity measures, financial aid measures, graduate enrollment measures, and so on. Some thematic "groups" included only one variable, e.g., percentage of undergraduates who were enrolled as part-time students. Other groups were comprised of two variables; for pairs, each variable was first modeled alone, and then modeled in conjunction with its companion measure (this allowed us to assess if a variable's predictive power was independent of a related measure—and which of the two was the stronger predictor). Ten sets of Level 2 models were constructed according to this heuristic.

$\eta_{2ij} = \beta_{0j(2)}$ + [student background characteristics (2 measures) + educational experiences/attitudes (7 measures) + major (8 measures) + expected salary (1 measure) in the form $\sum\beta_{qj(2)}X_{qij}$]

Where η is the log-odds of being in category (1) or (2) relative to category (3) as a function of the group mean (β_0) and covariates (X).

At Level 2, the model is given by:

$$\beta_{0j(1)} = \gamma_{0(1)} + \sum\gamma_{0s(1)}W_{sj} + \mu_{0j(1)}$$

$$\beta_{0j(2)} = \gamma_{0(2)} + \sum\gamma_{0s(2)}W_{sj} + \mu_{0j(2)}$$

$$\beta_{qj(m)} = \gamma_{q0(m)} \quad q=1,\ldots,18.$$

Where the group mean is a function of the grand mean (γ_0) and covariates (W).

Each Level 2 variable was centered around the grand mean. As with the Level 1 models, non-dichotomous variables were standardized prior to centering. Level 2 models were constructed for the multinomial analyses only. Calculations for Level 2 measures are described below.

Post hoc analyses

Post-hoc univariate analyses were conducted to elaborate on findings from multivariate models. These included one-way ANOVAs with posthoc multiple comparisons. Welch robust tests of equality of means were used where variance was heterogeneous; for pairwise comparisons, Bonferroni tests were used in the case of homogenous variance, and Games-Howell tests were used in the case of heterogeneous variance.

Measures

Outcome measures

In order to measure students' post-graduation plans, the APPLES instrument asked students "How likely is it that you would do each of the following after graduation?" and listed four possible options: "work in an engineering job," "work in a non-engineering job," "go to graduate school in an engineering discipline," and "go to graduate school outside of engineering."[5] Each item was measured on a five-point scale, from 0="definitely not" to 4="definitely yes." Respondents were then placed into one of three analytic groups based on combinations of responses across all four post-graduation categories:

- "Engineering focused students" are those who marked probably/definitely yes to one or both engineering options (job, graduate school) and probably/definitely no to both non-engineering options (job, graduate school);
- "Non-engineering focused students" are those who marked probably/definitely yes to one or both non-engineering options and probably/definitely no to both engineering options; and
- "All other plans" include all other possible response combinations to the four post-graduation survey items.

A second classification was developed in order to analyze a more focused subset of students falling into the "all other plans" group. In this classification, "all other plans" was replaced by "cross-field plans," which includes only those response combinations where students marked probably/definitely yes to at least one engineering option and one non-engineering option. This refinement reduced the sample for analysis from 2,143 students to 1,318 students.

To support interpretation of the multinomial results, each of the four constituent pathways questions (likelihood to "work in an engineering job," "work in a non-engineering

[5] In other words, students were not presented with a list of specific engineering jobs on the APPLES instrument. Rather, they were asked about engineering jobs in the aggregate; the intention was to elicit students' interest in "engineering jobs" as they conceived them to be.

job," and so on) was also modeled separately with the same Level 1 specification. We do not present the results of these auxiliary analyses in detail in this paper, but reference them when necessary to clarify discussion of the MLR results. Detailed results of these analyses are available upon request.

Level 1 measures

SES. Students' self-reported socioeconomic background was captured in a survey item labeled "perceived family income" (asked on the APPLES instrument as "Would you describe your family as: …"). This item was measured on a five-point scale, from 0 = "low income" to 4 = "high income."[6]

Major. For the present study, we tested nine major fields of study: aerospace engineering, "bio-x" engineering, chemical engineering, civil and environmental engineering, computer science engineering, electrical engineering, industrial engineering, mechanical engineering, and "other engineering." "Bio-x" is so titled to account for the range of bio-engineering programs across institutions, e.g., bioengineering, biomedical engineering, etc. The majority of institutions in the APPLES sample house civil and environmental engineering in one department, so these majors were aggregated; the aggregate major includes 280 respondents marking "civil" and 22 respondents marking "environmental." Computer science engineering includes only those students marking on the survey "computer science/engineering (in engineering)" (as distinct from a computer science program outside of engineering). "Other engineering" includes the following APPLES major categories: agricultural engineering, construction engineering, engineering math and physics, engineering operations research and business, general engineering, materials and metallurgical engineering, nuclear engineering, ocean engineering, and other engineering. Two APPLES institutions offer a "general engineering" degree only; all respondents at these two schools are classified as "other engineering" majors. Mechanical engineering is the reference group for all regression models.

Expected salary. Drawing from BLS 2007 median annual wage data by state, each student was assigned an expected salary given her/his engineering major and state in which her/his college was located. BLS engineering fields generally correspond with APPLES majors, with the following calculations noted:

- In the APPLES data, students in civil and environmental engineering majors are included in one major group, given that these two majors are typically represented in the same department/program on APPLES campuses. However, civil engineering majors are assigned a median salary for civil engineers, and environmental engineering majors are assigned a median salary for environmental engineers.

[6] "Mother's education," an alternate indicator of students' socioeconomic status, was also measured on the APPLES instrument. Among the students in our sample, the simple correlation between perceived family income and mother's education is moderate (r=.34, p=.000, n=2057). For the present analyses, all multivariate models were re-run with mother's education instead of perceived family income as the SES indicator at Level 1; mother's education shows an identical pattern of effects, although it has generally weaker predictive power than does perceived family income. This is consistent with the findings of Sheppard et al. (2010). See Donaldson, Lichtenstein, and Sheppard (2008) for a discussion of the history of SES measures in the APPLES study.

- Students in computer science engineering majors were assigned an average median salary across three BLS fields: computer hardware engineers, computer software engineers: applications, and computer software engineers: systems software.
- Students in bio-x engineering majors were assigned a median salary for biomedical engineers.
- For students in the "other engineering" major group, a "match" to BLS data was made wherever possible, e.g., materials engineers classified in our "other engineering" major group were assigned a median salary for materials engineers using BLS data. However, median salaries for these "other" fields were not available for every field in every state; in the case of a non-match, these students were assigned a median salary for the BLS "other engineering" category.

Controls. Several variables in earlier work on the APPLES dataset emerged as consistently strong predictors of students' post-graduation plans (see Introduction); these variables comprise the Level 1 control variables for the models in the present study. They include: *Financial motivation*, a three-item composite measure of students' financially-motivated reasons to pursue engineering study; *Intrinsic psychological motivation*, an three-item composite measure of students' "intrinsic" reasons to pursue engineering study; *Exposure to engineering work*, a single-item variable asked on the survey instrument as "How much exposure have you had to a professional engineering environment as a visitor, intern, or employee?" and measured on a four-point scale from 0 = "no exposure" to 3 = "extensive exposure"; *Involvement in engineering classes*, an four-item composite measure of students' engagement in their engineering coursework; *Participation in non-engineering activities*, a single-item variable asked on the survey instrument as "How often are you involved in the kinds of non-engineering activities described above [hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc.]?" and measured on a four-point scale from 0 = "never" to 3 = "frequently"; *GPA Index* (self-reported), measured on an eight-point scale from 0 = "C- or lower" to 7 = "A or A+" (and then converted to a 100-point scale); and *Professional/interpersonal confidence*, a six-item composite measure of students' self-concept in professional and interpersonal domains. Responses to survey items comprising each composite measure were summed and normalized prior to standardizing. See Appendix B for a list of constituent items in each composite measure and corresponding Cronbach's alpha values.

As noted earlier, gender and underrepresented racial/ethnic minority (URM) status were tested as separate measures in a preliminary series of models; final models included a measure for "URM women" only given results suggesting that this group of students had unique post-graduation plans. Students classified as URM include those marking American Indian/Alaska Native, black/African American, Hispanic/Latino(a), and Native Hawaiian/Pacific Islander racial/ethnic backgrounds.

Level 2 measures

Level 2 measures were selected from IPEDS and ASEE datasets. Measures that reflected institutional resources and selectivity were the focus of analysis; these included SAT composite scores among incoming enrollees, percentage of part-time undergraduates, student-to-faculty ratio (in engineering schools and institution-wide), and institutional control (public vs. private).

Measures also included those relating to undergraduate, graduate, and total enrollment, in order to triangulate statements about resources. Among all possible undergraduate financial aid measures in IPEDS (percentage receiving aid from institutions, aid from state/local institutions, etc.), it was determined that federal aid and student loan aid would help to clarify the socioeconomic resources of the institution (vis-à-vis students' socioeconomic resources) and would (inversely) link to institutional selectivity (see Astin, 1993; Astin & Oseguera, 2004; Titus, 2006). Proportional size of undergraduate and graduate engineering programs was tested as an exploratory measure of resources. The process by which undergraduates declared their engineering major at each school was a measure of interest in earlier APS work and was tested in this analysis as well; while there is not an overt link to selectivity and resources, "major declaration process," in addition to admissions policies at engineering schools, could influence students' perceptions of and movement into/out of engineering (see Garrison et al., 2007; Lichtenstein et al., 2009).

Calculations for each institutional characteristic in the Level 2 model sequence are as follows (data are aggregated to the level of the institution and/or represent institution averages; the source for each measure is in parentheses):

Set 1: Academic selectivity

- *SAT composite*: Calculated as the sum of SAT-Math 75th percentile score (IPEDS) and SAT-Critical Reading 75th percentile score (IPEDS)
- *SAT ratio*: Calculated as a ratio of SAT-Math 75th percentile score (IPEDS) to SAT-Critical Reading 75th percentile score (IPEDS)

SET 2: Percentage of undergraduates receiving financial aid

- *Percentage undergraduates receiving federal grant aid* (IPEDS)
- *Percentage undergraduates receiving student loan aid* (IPEDS)

SET 3: Percentage of part-time undergraduates

- *Percentage of undergraduates who are part-time students*: Estimated undergraduate enrollment, part time (IPEDS)/Estimated undergraduate enrollment total (IPEDS)

SET 4: Institutional type: Undergraduate/graduate

- *Nearly exclusive undergraduate institution vs. Institution with graduate students*: Dichotomous measure based on percentage of total students who are graduate students (see below) and triangulated with Carnegie Classification: Enrollment Profile and Carnegie Classification: Size and Setting (IPEDS); in this classification, institutions with less than 10 percent of their total population who are graduate students are classified as a "nearly exclusive undergraduate institution"
- *Percentage of total students who are graduate students*: Estimated graduate enrollment total (IPEDS)/Estimated enrollment total (IPEDS)

SET 5: Size of institution and engineering programs: Total enrollments

- *Estimated enrollment total* (IPEDS)
- *Percentage of total students enrolled who are in engineering*: Grand total Engineering, All students (IPEDS)/Estimated enrollment total (IPEDS)

SET 6: Size of institution and engineering programs: Undergraduate enrollments

- *Estimated undergraduate enrollment total* (IPEDS)

- *Percentage of undergraduate students enrolled who are in engineering*: Grand total Engineering undergraduate total (IPEDS)/ Estimated undergraduate enrollment total (IPEDS)

SET 7: Size of institution and engineering programs: Graduate enrollments

- *Estimated graduate enrollment total* (IPEDS)
- *Graduate engineering students as a proportion of all engineering students*: Grand total Engineering graduate total (IPEDS)/Grand total Engineering, All students (IPEDS)[7]

SET 8: Student-to-faculty ratio

- *Student-to-faculty ratio* (IPEDS)
- *Engineering student-to-faculty ratio*: Calculated as a ratio of total engineering undergraduates (full-time plus part-time) (ASEE) to engineering teaching faculty (tenure/tenure track plus non tenure track) (ASEE)

SET 9: Major declaration process

- *Student enters institution in engineering program vs. Student declares engineering major later, after matriculation*: Dichotomous measure based on APPLES institutions' program profiles

SET 10: Institutional control

- *Public institution vs. Private institution*: Dichotomous measure based on APPLES institutional profiles

FINDINGS

Post-Graduation Plans of Engineering Students

The APPLES survey allowed us to examine post-graduation plans relative to pursuing a job in the labor market and/or attending graduate school in engineering or outside of engineering. Survey respondents indicated their post-graduation plans for work or graduate school in four separate questions, as illustrated in the first panel of Table 1. Plans for working as a practicing engineer were most common among students (~81%), much more common than plans for obtaining a non-engineering job. Graduate school plans, however, were mixed. Forty-three percent of students indicated plans for attending a graduate program in engineering, and nearly one-third indicated graduate plans in other fields. Clearly, many students indicated some degree of interest in both engineering and non-engineering options.

Insert Table 1 about here

As described earlier, we created two sets of mutually exclusive categories of students from those four separate questions, in order to understand student retention in engineering careers more fully. Examining these exclusive categories in the second panel of the table, we see that a considerable majority of junior and senior engineering students have not ruled out future employment or education in both engineering and non-engineering fields. In fact, less than 30 percent of students are strictly engineering focused in their plans. Among respondents in the

[7] "Percentage of graduate students enrolled who are in engineering" cannot be calculated because two institutions in the sample do not have graduate student enrollments.

smaller subsample, there are nearly equal proportions of students who are engineering focused and have cross-field plans.

The distribution of men and women across our categories of post-graduation plans differs somewhat from the overall sample (see Table 2). Women are about 34 percent more likely than men to indicate non-engineering focused post-graduation plans and 13 percent more likely to indicate cross-field plans.

Insert Table 2 about here

Given the relative dearth of data on the roles of socioeconomic status (SES) and engineering sub-field in retention in or movement out of engineering, we also examined the distribution of post-graduation plans by perceived family income and undergraduate major (Table 2). Although the trends do not appear linear, high income students tend to have the lowest rates of engineering focused plans and the highest rates of non-engineering focused plans. In both the full and refined samples, for example, high income students indicate non-engineering focused plans at more than double the rate as their low income peers.

With regard to major, there are several differences that stand out in Table 2. Civil and environmental engineers are the most focused on engineering jobs and/or graduate study, and the least focused on non-engineering jobs and/or graduate study. At over a third in the refined sample, bio-x majors are the most focused on non-engineering pathways. The largest proportion of students interested in both engineering and non-engineering options is observed among the industrial engineers in the sample; industrial engineering majors also have the lowest rates of engineering focused plans across all major groups.

Level 1 MLR Results – Student Factors

While the tables above indicate individual relationships between post-graduation plans and gender, SES, and major, multinomial logistic regression allows us to examine these and a number of additional factors simultaneously. Estimates of regression coefficients indicate those variables which best distinguish students in one category of post-graduation plans from another. Table 3 shows the results of two Level 1 HGLM models, one examining the full-sample categories and one examining the refined-sample categories. In both models, engineering focused students are the reference group. Our analyses largely replicate the design of the earlier APPLES project (see Sheppard et al. 2010), but add major and expected salary by field and state to the models, and examine the degree of focus in engineering or non-engineering career plans among undergraduate engineers.

The patterns for control variables in both full and refined sample multinomial models are consistent with those found in earlier work: intrinsic psychological motivation to study engineering, financial motivation to study engineering, exposure to the engineering profession, academic involvement in engineering, and self-reported academic achievement are associated with plans oriented to engineering. Engagement in non-engineering extracurricular activities and greater interpersonal and professional skills are associated with non-engineering post-graduation plans. Note also that for most of the variables in the models, statistically significant coefficients

for the full and refined samples are similar in magnitude, as are the standard errors. In a few cases, coefficients for the same variable differ considerably across the two models, which may indicate sensitivity to either sample size or the different compositions of the "all other plans" and "cross-field plans" categories. Those particular results should be interpreted with caution. One notable exception is the results for GPA. GPA differentiates students with engineering focused plans from those with "all other plans," but not from those with specific cross-field plans (see second panel of Table 3). Moreover, in separate HLM models of each constituent pathway, GPA is a negative predictor of plans to pursue an engineering job ($b=-.59$, $p<.001$) and a positive predictor of plans to pursue engineering graduate school ($b=.20$, $p<.001$). There is no significant relationship between GPA and plans for non-engineering jobs or graduate study. Although GPA is not the focus of the current work, it is important to consider how academic indicators differentiate students with specific types of engineering post-graduation plans, and "how doing well in school" may be a lead-in for "doing more school"—and not practicing engineering professionally.

Insert Table 3 about here

With those previously identified factors statistically controlled, we focus on relationships between post-graduation plans and SES, major, and the labor market. Given previous analyses of this dataset, we also examine relationships between post-graduation plans and underrepresented minority (URM) women. As the second panel of Table 3 shows, URM women are a significant indicator of having cross-field plans (refined sample only). Although our measure of SES — perceived family income — is negatively correlated with plans for pursuing an engineering job and an engineering graduate degree ($r=-.13$ and $r=-.14$, respectively, $p<.001$), it does not distinguish engineering focused students from others in the MLR analysis.

Specific engineering majors, however, do exhibit differences. Relative to students in mechanical engineering, civil/environmental engineering majors are more likely to report career plans that are strictly engineering focused. In fact, it is the only major group that is associated with engineering focused plans. Students who are bio-x and chemical engineering majors, on the other hand, have 3 to 5 times the odds of having non-engineering plans as do mechanical engineering majors (calculated by exponentiating coefficients). Industrial engineers (full sample only) tend to report mixed plans. All other majors show no relationship to post-graduation plans.

Labor market influences were measured by field-specific median salaries in the state where a respondent's university is located. Across all states represented in our sample, salaries varied considerably with major (see Table 4), with aerospace and computer engineers fetching the highest salaries on average, and biomedical and civil engineers earning the lowest. In our full-sample MLR model, higher salaries differentiated engineering focused students from non-engineering focused ones.

Insert Table 4 about here

Level 2 MLR Results – Institutional Factors

At Level 2, we tested for institutional factors that may be related to students' continuing pathways in or beyond engineering. As noted earlier, we examined 18 institutional characteristics with ten separate models because of the limited number of institutions in our sample. Statistically significant ($p < .05$) results are captured in Figure 1 and include estimated coefficients for the full sample only. Because of the small number of institutions in the APPLES sample, these results should be interpreted with caution.

Insert Figure 1 about here

[*Note to be placed under Figure 1:* Predictors are significant at p<.05 holding all Level 1 variables constant. Due to limitations of institutional sample size (N=21), each variable was tested in a separate model. Standard errors are available on request. See Methodology for additional details.]

Relative to engineering focused students, non-engineering focused students are more likely to attend institutions that enroll undergraduate populations with higher SAT scores, lower rates of federal financial aid receipt, and lower rates of part-time attendance. Students attending private institutions in our sample also are more likely to be non-engineering focused than are their counterparts at public institutions. The magnitudes of the coefficients for the standardized variables suggest that institution-level SES (as reflected by the receipt of aid) is the strongest differentiator of post-graduation plans. We note that several of these institutional characteristics are intercorrelated, with the strongest correlation observed between SAT composite score and private institutions ($r=.81$, $p<.001$) and SAT composite score and percentage of students receiving federal aid ($r=-.78$, $p<.001$).

Notably, the size and types of programs did not differentiate post-graduation plans. In particular, the manner in which engineering majors are declared (upon admission or during matriculation) does not appear to be related to persistence in engineering post-baccalaureate. The lone exception among these variables is graduate student enrollment, such that undergraduate engineering majors attending institutions with greater proportions of graduate students also tend to have non-engineering post-graduation plans (see Figure 1).

Institutional characteristics did not differentiate students with engineering focused plans from those with "all other plans" or the more specific "cross-field plans" subset.

The next sections build on the results of these MLR models and draw from additional analyses to explore the role of SES, the labor market, and major field of study more deeply.

Exploring the Role of SES

In addition to the MLR analyses in Table 3, we examined the results of HLM analyses of each constituent variable of our constructed categorical measure of post-graduation plans (e.g., the Likert-scaled response to "How likely is it that you would work in an engineering job after graduation?"). These analyses indicate a negative relationship between perceived family income and plans to work ($b = -.56$, $p<.001$) or to study ($b = -.10$, $p<.001$) in an engineering field, holding all other variables in the model constant. Since SES does not emerge as significant in the

MLR analyses, we conducted additional post hoc analyses to better understand its role in the post-graduation plans of engineering students.

Table 5 shows how low, middle, and high income students differ by major and by institutional characteristics that were related to plans in the MLR analyses. Patterns by major are apparent in ways that we would expect given the results in Tables 2 and 3. Compared to low income students, slightly greater proportions of high income students major in fields associated with non-engineering post-graduation plans (bio-x, chemical, and industrial) and a somewhat smaller proportion major in civil/environmental engineering, which is associated with engineering focused plans. These differences are not significantly different from zero, however.

With respect to institutional factors, we earlier found that more selective and private institutions were associated with non-engineering focused plans. Table 5 indicates the expected trend between SES and selectivity and SES and control, such that high income students are significantly more likely to attend more selective as well as private institutions. Specifically, low income students are 56 percent less likely than are high income students to attend the most selective schools in our sample, and over two times more likely to attend the least selective institutions. Further, high income students are 42 percent more likely to attend a private institution. Qualities of the student body that predict engineering focused plans are also associated with SES. Consistent with existing literature (Astin, 1993; Astin and Oseguera, 2004), low income students are more likely than are high income students to attend high financial aid institutions and schools with greater part-time attendance. They are less likely to attend schools with high percentages of graduate student enrollments. Each of these patterns suggests that institutions play a role in the differing post-graduation destinations of low and high SES engineers.

Taken together, these data point to a number of individual and institutional factors that appear to be correlated with students' self-reported family income level, and help us to understand how SES may be factored into the future plans of engineering students.

Insert Table 5 about here

Exploring the Role of the Labor Market

As Table 3 shows, students' expected salary in the engineering labor market, as determined by their major field of study and state in which their college or university was located, modestly differentiates students who have engineering focused post-graduation plans from students who have non-engineering focused plans. Expected salary does not emerge as a significant predictor of constituent pathways (engineering job, non-engineering job, engineering graduate school, non-engineering graduate school), holding other variables constant, but is positively correlated with plans to pursue engineering graduate study ($r=.13$, $p<.001$) and weakly but negatively correlated with plans to enter an engineering job ($r=-.05$, $p<.05$). Computer science engineering majors in the APPLES sample have not only the highest rate of intention to pursue engineering graduate school (51% reporting "probably" or "definitely" yes), but also among the highest expected salaries (Table 4), which may help to explain the association between salary and graduate school that "disappears" when major is controlled in the HLM

model. Moreover, computer science engineering majors are less likely to have plans to pursue an engineering job after graduation (as compared with the reference group of mechanical engineers) in the HLM model of this pathway, which may help to explain the negative simple correlation between salary and plans for engineering job.

The modest role of expected salary in these models does not mean that financial motivation is not at work for students. Financial motivation to pursue engineering studies differentiates students with engineering focused plans from those focused on non-engineering options (Table 3); in the auxiliary models of constituent pathways, it is a positive predictor of plans to work in an engineering job after graduation ($b=.93$, $p<.001$). Interestingly, there is no difference in mean financial motivation by students' perceived family income. Further research needs to tease out the interaction between students' financial motivations, students' perceptions of the labor market, and actual labor market characteristics (e.g., median salaries of engineering jobs and alternatives, regional composition of firms and industries relative to the location of students' universities).

Exploring the Role of Major Field of Study

Table 2 compares the proportions of students in each major who have engineering focused, non-engineering focused, or cross-field post-graduation plans (as a percentage of the refined sample). The "cross-field plans" category allows us to talk more directly about the career plans among students who are neither engineering nor non-engineering focused. These are students who indicate strong interest in pursuing at least one of two engineering pathways (job or graduate school) and at least one of two non-engineering pathways (job or graduate school). There is wide variation by major in such plans. In the refined sample, students with an engineering focus to their plans varies from 17 percent (industrial engineering majors) to nearly 65 percent (civil and environmental majors), whereas students with a non-engineering focus varies from 4 percent (civil and environmental majors) to 35 percent (bio-x majors). Civil and environmental engineering majors are least likely to have cross-field plans (30.9%), and industrial engineering majors are most likely (60.5%).

We examined how motivation to study engineering varies by major as a way to probe these differences more deeply. The results are shown in Table 6. Our discussion is framed around two clusters of majors: those with 40 percent or more who are engineering focused (aerospace, civil/environmental, computer science/engineering, mechanical, electrical, and other engineering) and those with less than 40 percent who are engineering focused (bio-x, chemical, industrial). Note that the motivation means are calculated among the full sample of respondents even as the clusters are demarcated by refined sample proportions.

Insert Table 6 about here

Among the cluster of majors with 40 percent or more of engineering focused students are among the oldest fields in engineering, as established by the year in which the fields' professional societies were established: the American Society of Civil Engineering (1852), the American Society of Mechanical Engineers (1880), and the Institute of Electrical and Electronic Engineers (1884). Students in these fields report comparatively higher levels of intrinsic

psychological motivation to pursue engineering studies. Civil engineering is the outlier in this cluster. Multivariate models of constituent pathways indicate strong interest among these students in both engineering jobs and engineering graduate school holding constant other explanatory variables. Civil/environmental engineering majors in fact have the highest rate of engineering focused plans (Table 2). We also note that civil engineering majors earn the lowest salaries across all fields considered (Table 4). Thus, even among this cluster of engineering majors who are highly motivated for psychological reasons to study engineering, civil/environmental engineers distinguish themselves in terms of commitment to the field (in spite of their relatively lower expected salaries).

In the second cluster, less than 40 percent of students have engineering focused plans. This cluster contains two of the more recently created engineering fields, industrial engineering and bio-engineering (the Institute of Industrial Engineers was established in 1948, and the American Institute for Medical and Biological Engineering was established in 1991). Among bio-x majors, students are fairly evenly distributed across engineering-only, non-engineering only, and cross-field plans categories. Students in bio-x majors also exhibit lower financial motivation than any other group, and the highest proportion of students who are considering non-engineering-only career options, including non-engineering graduate school. Perhaps bio-x students see graduate school as an opportunity to expand their skills in the biological sciences, medicine, and/or business, all fields that are relevant to today's bio-x applications.

Bio-x students stand in contrast to industrial engineering majors, where far fewer students (17.4%) report engineering-only plans, and well over half report cross-field plans. Table 6 shows that industrial engineering majors are significantly less psychologically motivated to study engineering than are bio-x majors. In fact, industrial engineering majors are significantly less psychologically motivated than are students in every other major group except chemical engineering. Industrial engineering majors also have the highest rates of financial motivation—significantly higher that students in aerospace engineering programs, and marginally higher than students in all other major groups—which suggests that they may be aiming to explore both the technical and business worlds.

Motivation does not substantially differ between women and men within major in the APPLES sample (e.g., women industrial engineering majors are neither more nor less financially motivated to study engineering than are men industrial engineering majors). However, motivational differences between majors are more pronounced among women in our sample than among men. Recent work suggests that women may pursue engineering degrees for different reasons than do men (Orr et al., 2009), which might help to explain why there are different proportions of women and men in engineering sub-fields to begin with (NSF, 2011).

DISCUSSION

This study of late-stage engineering majors (juniors and seniors) across 21 U.S. institutions has opened a window into how today's engineering students conceive of their professional futures, and how educational and employment contexts may play a role in their plans. From multivariate models, we have learned that students who are engineering focused in their post-graduation plans are more psychologically and financially motivated to pursue

engineering studies than are those who are non-engineering focused. These students tend to be highly involved in their engineering coursework, have had exposure to the engineering profession, and have lower levels of professional/interpersonal confidence. Students with higher expected engineering salaries given their field of study and location are more likely to be zeroing in on engineering pathways as opposed to non-engineering pathways (although this effect is relatively small). They also are more likely to be attending public, less-selective institutions in the APPLES sample, and institutions that have higher percentages of part-time undergraduates and undergraduates receiving federal financial aid.

In addition, APPLES findings show that post-graduation plans of students vary by engineering major. For example, many more students majoring in civil and environmental engineering have engineering focused career plans than do students majoring in bio-x engineering or industrial engineering. We also see differences in psychological and financial motivation by major. It may be that motivation has both a direct relationship with post-graduation plans and an indirect relationship, operating through self-selection into certain fields. For example, are students with high levels of financial motivation drawn to industrial engineering programs, where there may be more examples of bridging engineering and non-engineering pathways for higher financial returns? How does motivation work for engineers in biomedical and bioengineering fields—with high percentages of non-engineering plans and relatively lower levels of financial motivation to study engineering, are these students "in it" for something else?

The interpretation above assumes that the effects of major are incidental to the institution in that students take cues from the field and translate them into decisions of major choice. A quite different interpretation assumes that student experiences in the major influence post-graduation choices. Cultural distinctions between the engineering fields can be present among various departments of engineering in a college, thereby exposing students to distinctive values, norms, and expectations pertaining to their major. This is precisely what Petrides (1996) observed in her study of academic cultures in engineering. Petrides studied the environments of five academic departments (Aerospace Engineering, Chemical Engineering, Electrical Engineering, Industrial Engineering and Mechanical Engineering) and found connections between departmental cultural characteristics (e.g., prestige of the field, what motivated people to be in the field, percent women in the field) and graduate students' post-graduation plans. All of this suggests that different branches of engineering attract and socialize individuals in different ways, and provide distinct and varied platforms for connecting school to work. To consider the "engineering school experience" or "engineering work" in the aggregate is to lose these important distinctions.

We also note that socioeconomic status appears to be playing an important, though somewhat distributed role in the pathways to engineering focused careers. Undoubtedly, one of the pull factors into the engineering profession is the promise of one of the better immediate returns on education in the form of salaried compensation (Carnevale, Rose, and Cheah, 2011; Carnevale, Strohl, and Melton, 2011). It is not clear if lower SES students see a career in engineering as a means to realize greater returns on their education more so than do higher SES students (one line of research suggests that lower SES students do not have differing perceptions of college returns than do their higher SES peers [Rouse, 2004], and do not in fact have different

returns to a bachelor's degree versus a high school diploma [Perna, 2003], but this research has not been conducted on engineering students per se). We do find, however, that lower SES students tend to matriculate at less selective, public institutions and institutions that enroll greater proportions of part-time students and students receiving financial aid. The results linking these institutional characteristics to engineering focused students imply a peer effect at such institutions that favors engineering focused pathways. And while public and less selective institutions may not be intentionally creating norms around engineering career pathways, such norms may be developed by the students (who are more often lower income) they tend to attract and enroll. Unfortunately, we cannot ascertain the veracity of this explanation in this study due to the nature of the APPLES data. More focused study of the normative expectations for post-graduation pathways at more/less selective colleges, public/private institutions, and more generally those that enroll primarily lower/higher SES students is recommended to better understand these relationships.

Situating Findings in Light of New National Data on the ECP

Among APPLES engineering majors, over 80 percent report engineering job plans. At the same time, when we consider how plans might include both engineering and non-engineering career options, or one set of options to the exclusion of the other, less than 30 percent report engineering focused plans. A small percentage—7 percent—have non-engineering focused plans. The majority of students have cross-field, mixed, or unclear plans. Of all 2,143 students in this sample, 577 (27%) have cross-field plans, i.e., these students marked "definite" or "probable" plans to pursue both engineering and non-engineering pathways. How might these plans manifest themselves into actions? To address this question, we draw on findings from the National Survey of Recent College Graduates (NSRCG), as analyzed and reported in Sheppard et al. (forthcoming).

Sponsored by the NSF's Division of Science Resource Studies, the NSRCG is administered every three years to recent recipients of bachelor's or master's degrees in science, engineering, and health fields. In April 2006, the NSRCG was administered to over 18,000 individuals who had graduated from 295 institutions during the 2002-2003, 2003-2004, and 2004-2005 academic years (NSF, 2006). These data show that some two years post-graduation, 60 percent of engineering graduates were working in an engineering job, 18 percent were working in other science and engineering-related fields[8], and 14 percent were working in non-engineering-related fields (for a total of 32 percent working outside of engineering) (the balance were in school or not employed). Thus, although about one-third of APPLES junior and senior engineering majors have engineering focused post-graduation plans (a group that characteristically is quite distinct from those with non-engineering focused plans), these data suggest that far more students may have engineering jobs two years out. Given the patterns that emerged in the APPLES data, it is worth considering how many of these practicing engineers have long-term career interests spanning multiple occupations and/or industries (resonant of APPLES' "cross-field" respondents), single out engineering as their long-term profession (resonant of APPLES' engineering focused respondents), or still have some uncertainty about

[8] Other science and engineering-related fields include computer and mathematical sciences, life sciences, physical sciences, social sciences, and "other" related fields.

their career pathways (similar to the larger group of students who fall into APPLES' "all other plans" category).

There are differences by field in the NSRCG data. For example, although nearly three-quarters or more of civil engineering, chemical engineering, and mechanical engineering majors reported that their occupation two years out was in engineering, civil engineering majors reported the highest rates of working in the same field as their major. This is consistent with APPLES findings of civil/environmental engineers as having the highest rate of engineering focused plans.

Where the NSRCG data provide particularly unique types of insight is in the career pathways of students who do not work in engineering jobs after graduation. These data allow us to distinguish between graduates who have gone into non-engineering technical work from those who have pursued non-technical work. This tells us that we might expect at least some of the 26 percent of engineering majors who plan to pursue non-engineering jobs (at some point in their professional futures—see Table 1) to end up in technology-based work outside of engineering. We can also assume/speculate that for a variety of reasons[9] some engineering students who have aspirations for engineering work will end up in non-engineering technology-based work.

Sheppard et al. (forthcoming) provide a fuller discussion of these patterns. Additional research is needed, over an even longer time period, to understand engineering graduates' pathways into other science and engineering-related fields (and/or into non-engineering fields, vis-à-vis master's- or doctoral-level training in business, biological sciences, information sciences, and the like), such that academic institutions and programs can better support them.

CONCLUSION AND IMPLICATIONS

These data indicate many next steps for research on the ECP, bridging work on "persistence in the major" to "persistence in the profession" for a more complete picture of workforce trends among new graduates. Circling back to the broad questions posed at the very start of this chapter: most engineering majors see engineering jobs in their futures, but not all are focused on engineering to the exclusion of other, non-engineering plans; there is a distinctive profile of students who indicate engineering-focused plans, particularly relative to students who indicate non-engineering-focused plans, with major and institutional characteristics playing potentially important roles in this profile; and indeed, certain educational environments may provide more or less support for engineering focused plans, through norms, peers, professional opportunities, or otherwise, although the APPLES data do not allow us to identify how these dynamics might operate or make casual statements about impact. Future research might probe those areas that APPLES data are unable to address, to more fully establish the interconnected factors at play as students develop their career plans and enter the labor market.

As an example, in considering engineering pathways—how school connects with post-graduation employment—it is clearly important to look at fields within engineering. There are

[9] For example, among the primary reasons given by NSRCG for employment in a non-engineering position are "pay and promotion opportunities," "working conditions," "job location," "change in professional/career interests," "family," and "job in highest degree field not available."

significant differences by field in the ties between engineering education and engineering employment (i.e., working in one's "aligned" field). Researching pathways is complex and nuanced, needing to follow and capture these field-by-field distinctions when creating a picture of the school-to-work transition. How do undergraduate engineering programs reflect and reinforce field-by-field distinctions, and to what extent does this activity at the site of the major vary by institutional type? To what extent are peer effects at work, and/or more structured curricular and co-curricular norms and opportunities at each site? How do on-campus industry recruitment mechanisms—which may widely vary by institution and region—influence plans and actions within field and among different groups of students? How much of the field-by-field variation in school-to-work is explained by how students learn to conceive of their skill sets in their undergraduate training? To what extent is major itself a proxy for skills (in addition to culture), with historically strong industry drivers?

Findings in this chapter on variation in engineering vs. non-engineering focus by institutional selectivity and resources need to be explored in larger institutional samples and over longer periods of time, as do the professional outcomes of graduates at these different schools. To the extent that some institutions may be more or less conducive to pursuing engineering employment (as opposed to a broader array of career options), it is important to consider how policy at state and federal levels can support engineering pathways. Investments in public education and federal student aid, for instance, may play a role in bolstering the number of practicing engineers. Relatedly, how lower SES students conceive of engineering in the environments in which they tend to matriculate will be critical to understanding the role of individual and peer-based socioeconomic characteristics in the engineering workforce.

Finally, it is imperative to consider what happens in the actual span of time between graduation and workforce participation among engineering graduates. Which factors come into play above and beyond one's socioeconomic background, educational experiences, motivations, and confidence in certain domains? Which sets of opportunities and constraints matter most to the transition into the engineering labor market? How can this information help schools of engineering better prepare their graduates for what is ahead? These questions suggest rich roads for future research.

BIOGRAPHIES

Shannon K. Gilmartin is a Consulting Assistant Professor in Mechanical Engineering at Stanford University and Director of SKG Analysis. Anthony Lising Antonio is an Associate Professor of Education at Stanford University. Helen L. Chen is a Research Associate in the Department of Mechanical Engineering at Stanford University. Samantha R. Brunhaver is a Ph.D. candidate in Mechanical Engineering at Stanford University. Sheri D. Sheppard is a Professor of Mechanical Engineering at Stanford University.

ACKNOWLEDGEMENTS

This research was supported by grants from the National Science Foundation and Sloan Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect those of the NSF or Sloan.

REFERENCES

Adelman, Clifford. *Women and Men of the Engineering Path: a Model for Analyses of Undergraduate Careers.* Washington, DC: U.S. Department of Education and the National Institute for Science Education, 1998.

American Society for Engineering Education. "Engineering and Engineering Technology College Profiles for 2006," accessed September 1, 2011, http://profiles.asee.org/.

Anderson, Eugene and Dongbin Kim. *Increasing the Success of Minority Students in Science and Technology*. The Unfinished Agenda: Ensuring Success for Students of Color (American Council on Education Item #310736), edited by Peter D. Eckel. Washington, DC: American Council on Education, 2006.

Astin, Alexander W. *What Matters in College: Four Critical Years Revisited*. San Francisco, CA: Jossey Bass, 1993.

Astin, Alexander W., and Leticia Oseguera. "The Declining "Equity" of American Higher Education." *The Review of Higher Education* 27, no. 3 (2004): 321-341.

Atman, Cynthia J., Sheri D. Sheppard, Jennifer Turns, Robin S. Adams, Lorraine N. Fleming, Reed Stevens, Ruth A. Streveler, Karl A. Smith, Ronald L. Miller, Larry J. Leifer, Ken Yasuhara, and Dennis Lund. *Enabling Engineering Student Success: The Final Report for the Center for the Advancement of Engineering Education*. San Rafael, CA: Morgan & Claypool Publishers, 2010.

Besterfield-Sacre, Mary, Cindy J. Atman, and Larry J. Shuman. "Characteristics of Freshmen Engineering Students: Models for Determining Student Attrition in Engineering." *Journal of Engineering Education* 86, no. 2 (1997): 139-149.

Besterfield-Sacre, Mary E., Magaly Moreno, Larry J. Shuman, and Cynthia J. Atman. "Gender and Ethnicity Differences in Freshmen Engineering Student Attitudes: A Cross-Institutional Study." *Journal of Engineering Education* 90, no. 4 (2001): 477 - 489.

Borrego, Maura, Miguel A. Padilla, Guili Zhang, Matthew W. Ohland, and Timothy J. Anderson. "Graduation Rates, Grade-Point Average, and Changes of Major of Female and Minority Students Entering Engineering." In *Proceedings of the ASEE/ISEE Frontiers in Engineering Conference, Indianapolis, IN, October 19-22, 2005.*

Brainard, Suzanne G., and Linda Carlin. "A Six-Year Longitudinal Study of Undergraduate Women in Engineering and Science." *Journal of Engineering Education* 87, no. 4 (1998): 369-375.

Bureau of Labor Statistics. "National Cross-Industry Estimates, May 2006," accessed September 1, 2011, http://www.bls.gov/oes/2007/may/oes_dl.htm#2007

The Carnegie Foundation for the Advancement of Teaching. *The Carnegie Classifications of Institutions of Higher Education (2000 Edition)*. Menlo Park, CA: The Carnegie Foundation for the Advancement of Teaching, 2001.

Carnevale, Anthony P., Stephen J. Rose, and Ban Cheah. *The College Payoff: Education, Occupations, Lifetime Earnings*. Washington, DC: Georgetown University Center on Education and the Workforce, 2011.

Carnevale, Anthony P., Jeff Strohl, and Michelle Melton. *What's It Worth? The Economic Value of College Majors*. Washington, DC: Georgetown University Center on Education and the Workforce, 2011.

Chen, Helen L., Krista Donaldson, Özgur Eriş, Debbie Chachra, Gary Lichtenstein, Sheri D. Sheppard, and George Toye. "From PIE to APPLES: The Evolution of a Survey Instrument to Explore Engineering Student Pathways." In *Proceedings of the American Society for Engineering Education Annual Conference, Pittsburgh, PA, June 22-25, 2008.*

Clark, Mia, Sheri D. Sheppard, Cynthia J. Atman, Lorraine Fleming, Ronald Miller, Reed Stevens, Ruth Streveler, and Karl Smith. "Academic Pathways Study: Processes and Realities." In *Proceedings of the American Society for Engineering Education Annual Conference, Pittsburgh, PA, June 22-25, 2008.*

Donaldson, Krista, Helen L. Chen, George Toye, Mia Clark, and Sheri D. Sheppard. "Scaling Up: Taking the Academic Pathways of People Learning Engineering Survey (APPLES) National." In *Proceedings of the IEEE/ASEE Frontiers in Education Conference, Saratoga Springs, NY, October 22-25, 2008.*

Donaldson, Krista, Helen L. Chen, George Toye, and Sheri Sheppard. "Targeting Undergraduate Students for Surveys: Lessons from the Academic Pathways of People Learning Engineering Survey (APPLES)." In *Proceedings of the 37th Annual Frontiers in Education Conference, Milwaukee, Wisconsin, October 10-13, 2007.*

Donaldson, Krista, Gary Lichtenstein, and Sheri D. Sheppard. "Socioeconomic Status and the Undergraduate Experience: Preliminary Findings from Four American Universities." In *Proceedings of the American Society for Engineering Education Annual Conference, Pittsburgh, PA, June 22-25, 2008.*

Eriş, Özgür, Debbie Chachra, Helen L. Chen, Camelia Rosca, Larry Ludlow, Sheri D. Sheppard, and Krista Donaldson. "A Preliminary Analysis of Correlates of Engineering Persistence: Results from a Longitudinal Study." In *Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, Hawaii, June 24-27, 2007.*

Eriş, Özgür, Debbie Chachra, Helen L. Chen, Sheri D. Sheppard, Larry Ludlow, Camelia Rosca, Tori Bailey, and George Toye. "Outcomes of a Longitudinal Administration of the Persistence in Engineering Survey." *Journal of Engineering Education* 99, no. 4 (2010): 371-395.

Eriş, Özgür, Helen L. Chen, Tori Bailey, Kimarie Engerman, Heidi Loshbaugh, Ashley Griffin, Gary Lichtenstein, and Angela Cole. "Development of the Persistence in Engineering (PIE) Survey Instrument." In *Proceedings of the American Society for Engineering Education Annual Conference, Portland, Oregon, June 12-15, 2005.*

Fenske, Robert H., John D. Porter, and Caryl P. DuBrock. "Tracking Financial Aid and Persistence of Women, Minority, and Needy Students in Science, Engineering, and Mathematics." *Research in Higher Education* 41, no. 1 (2000): 67–94.

Garrison, Lari, Reed Stevens, Portia Sabin, and Andrew Jocuns. "Cultural Models of the Admission Process in Engineering: Views on the Role of Gender, Women in Engineering." In *Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, Hawaii, June 24-27, 2007.*

Huang, Gary, Nebiyu Taddese, and Elizabeth Walter. "Entry and Persistence of Women and Minorities in College Science and Engineering Education, NCES 2000-601." Washington, DC: U.S. Department of Education. National Center for Education Statistics, 2000.

Lichtenstein, Gary, Heidi G. Loshbaugh, Brittany Claar, Tori Bailey, and Sheri Sheppard. "Should I Stay or Should I Go? Engineering Students' Persistence Is Based on Little Experience or Data." In *Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, Hawaii, June 24-27, 2007.*

Lichtenstein, Gary, Heidi G. Loshbaugh, Brittany Claar, Helen L. Chen, Kristyn Jackson, and Sheri D. Sheppard. "An Engineering Major Does Not (Necessarily) an Engineer Make: Career Decision-Making Among Undergraduate Engineering Majors." *Journal of Engineering Education* 98, no. 3 (2009): 227-234.

Lord, Susan M., Catherine E. Brawner, Michelle M. Camacho, Richard A. Layton, Russell A. Long, Matthew W. Ohland, and Mara H. Wasburn. "Work in Progress: A Study to Investigate the Effect of Climate and Pedagogy on Persistence of Women in Undergraduate Engineering Programs." In *Proceedings of the IEEE/ASEE Frontiers in Education Conference, Saratoga Springs, NY, October 22-25, 2008.*

Lord, Susan M., Michelle M. Camacho, Richard A. Layton, Russell A. Long, Matthew W. Ohland, and Mara H. Wasburn. "Who's Persisting in Engineering? A Comparative Analysis of Female and Male Asian, Black, Hispanic, Native American and White Students." *Journal of Women and Minorities in Science and Engineering* 15, no. 2 (2009): 167–190.

National Center for Education Statistics. "Integrated Postsecondary Education Data System, 2006," accessed September 1, 2011, http://nces.ed.gov/ipeds/datacenter/Default.aspx.

National Science Foundation, Division of Science Resources Statistics. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2011*. Special Report NSF 11-309. Arlington, VA, accessed September 3, 2011, http://www.nsf.gov/statistics/wmpd/tables.cfm.

National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Statistical Data System (SESTAT). *2006 National Survey of Recent College Graduates*. Arlington, VA, accessed August 10, 2011, http://www.nsf.gov/statistics/sestat.

National Science Foundation, National Center for Science and Engineering Statistics. *Science and Engineering Degrees: 1966–2008.* Detailed Statistical Tables NSF 11-316. Arlington, VA, accessed September 3, 2011, http://www.nsf.gov/statistics/nsf11316/content.cfm?pub_id=4062&id=2.

Ohland, Matthew W., Catherine E. Brawner, Michelle M. Camacho, Richard A. Layton, Russell A. Long, Susan M. Lord, and Mara H. Wasburn, "Race, Gender, and Measures of Success in Engineering Education." *Journal of Engineering Education* 100, no. 2 (2011): 225-252.

Ohland, Matthew W., Michelle M. Camacho, Richard A. Layton, Susan M. Lord, and Mara H. Wasburn. "How We Measure Success Makes a Difference: Eight-Semester Persistence and Graduation Rates for Female and Male Engineering Students." In *Proceedings of the American Society for Engineering Education Annual Conference, Austin, TX, June 14-17, 2009.*

Ohland, Matthew W., Sheri D. Sheppard, Gary Lichtenstein, Özgur Eris, Debbie Chachra, and Richard A. Layton. "Persistence, Engagement, and Migration in Engineering." *Journal of Engineering Education* 97, no. 3 (2008): 259-278.

Orr, Marisa, Zahra Hazari, Philip Sadler, and Gerhard Sonnert. "Career Motivations of Freshman Engineering and Non-Engineering Students: A Gender Study." In *Proceedings of the American Society for Engineering Education Annual Conference, Austin, TX, June 14-17, 2009.*

Perna, Laura W. "The Private Benefits of Higher Education: An Examination of the Earnings Premium." *Research in Higher Education* 44, no. 4 (2003): 451-472.

Petrides, Lisa A. "A Study of the Gendered Construction of the Engineering Academic Context in Graduate School." PhD diss. Stanford University, 1996.

Raudenbush, Stephen W., and Anthony S. Bryk. *Hierarchical Linear Models: Applications and Data Analysis Methods* (2nd edition). Thousand Oaks, CA: Sage, 2002.

Rouse, Cecilia Elena. "Low-Income Students and College Attendance: An Exploration of Income Expectations." *Social Science Quarterly* 85, no. 5 (2004): 1299-1317.

Seymour, Elaine, and Nancy M. Hewitt. *Talking About Leaving: Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors.* Boulder, CO: University of Colorado, Bureau of Sociological Research, 1994.

Seymour, Elaine and Nancy M. Hewitt. *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, CO: Westview Press, 1997.

Sheppard, Sheri D., Shannon Gilmartin, Helen L. Chen, Krista Donaldson, Gary Lichtenstein, Özgur Eris, Micah Lande, and George Toye. *Exploring the Engineering Student Experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES) (TR-10-01)*. Seattle, WA: Center for the Advancement for Engineering Education, 2010.

Sheppard, Sheri D., Anthony L. Antonio, Samantha B. Brunhaver, and Shannon K. Gilmartin. "The Early Career Pathways of Engineering Students." In *Cambridge Handbook of Engineering Education Research*, edited by Aditya Johri and Barbara Olds. New York, NY: Cambridge University Press, forthcoming.

Titus, Marvin A. "Understanding College Degree Completion of Students with Low Socioeconomic Status: The Influence of the Institutional Financial Context." *Research in Higher Education* 47, no.4 (2006): 371-398.

Watson, Karan, and Jeffrey Froyd. "Diversifying the U.S. Workforce: A New Model." *Journal of Engineering Education* 96, no. 1 (2007): 19-32.

APPENDIX A. Participating APPLES institutions by Carnegie Classification

The 2000 Carnegie Classification (The Carnegie Foundation for the Advancement of Teaching, 2001) was used as the basis for the APPLES stratified institutional sampling plan (see Donaldson et al., 2008). The updated 2010 Carnegie Classification categories are presented for comparison.

Institution	2000 Carnegie Classification	Basic Carnegie Classification (2010)
Alabama A&M University	Doctoral/Research Intensive	Master's L: Master's Colleges and Universities (larger programs)
Arizona State University	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
CUNY New York City College of Technology	Master's Colleges and Universities I	Bac/Assoc: Baccalaureate/Associate's Colleges
Columbia University	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
Florida Atlantic University	Doctoral/Research Intensive	RU/H: Research Universities (high research activity)
Georgia Institute of Technology	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
Harvey Mudd College	Baccalaureate Colleges – Liberal Arts	Bac/A&S: Baccalaureate Colleges--Arts & Sciences
Kettering University	Specialized Institutions – Schools of Engineering and Technology	Master's M: Master's Colleges and Universities (medium programs)
Massachusetts Institute of Technology	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
Montana Tech of the University of Montana	Specialized Institutions – Schools of Engineering and Technology	Bac/Diverse: Baccalaureate Colleges--Diverse Fields
North Carolina A&T State University	Master's Colleges and Universities I	DRU: Doctoral/Research Universities
Northwestern University	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
Oklahoma Christian University	Baccalaureate Colleges – General	Master's M: Master's Colleges and Universities (medium programs)
Franklin W. Olin College of Engineering	Not Classified	Spec/Engg: Special Focus Institutions--Schools of engineering
Portland State University	Doctoral/Research Intensive	RU/H: Research Universities (high research activity)
Purdue University	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)
San Jose State University	Master's Colleges and Universities I	Master's L: Master's Colleges and Universities (larger programs)
Smith College	Baccalaureate Colleges – Liberal Arts	Bac/A&S: Baccalaureate Colleges--Arts & Sciences
University of Minnesota-Twin Cities	Doctoral/Research Extensive	RU/VH: Research Universities (very high research activity)

Institution	2000 Carnegie Classification	Basic Carnegie Classification (2010)
University of Texas at El Paso	Doctoral/Research Intensive	RU/H: Research Universities (high research activity)
West Virginia University Institute of Technology)	Baccalaureate Colleges – General	Bac/Diverse: Baccalaureate Colleges--Diverse Fields

APPENDIX B. COMPOSITE MEASURES USED IN MULTIVARIATE MODELS

(Question numbers refer to those on the APPLES instrument)

Motivation: Financial (α=.81)

Q9b. Reason for pursuing engineering studies: Engineers make more money than most other professionals[1]
Q9e. Reason for pursuing engineering studies: Engineers are well paid[1]
Q9g. Reason for pursuing engineering studies: An engineering degree will guarantee me a job when I graduate[1]

Motivation: Intrinsic Psychological (α=.75)

Q9k. Reason for pursuing engineering studies: I feel good when I am doing engineering[1]
Q9m. Reason for pursuing engineering studies: I think engineering is fun[1]
Q9o. Reason for pursuing engineering studies: I think engineering is interesting[1]

Confidence in Professional and Interpersonal Skills (α=.82)

Q11a. Self-rating compared to your classmates: Self confidence (social)[2]
Q11b. Self-rating compared to your classmates: Leadership ability[2]
Q11c. Self-rating compared to your classmates: Public speaking ability[2]
Q11f. Self-rating compared to your classmates: Communication skills[2]
Q11h. Self-rating compared to your classmates: Business ability[2]
Q11i. Self-rating compared to your classmates: Ability to perform in teams[2]

Academic Involvement—Engineering-Related Courses (α=.71)

Q16a. Frequency during current school year: Came late to engineering class (reverse-coded)[3]
Q16b. Frequency during current school year: Skipped engineering class (reverse-coded)[3]
Q16c. Frequency during current school year: Turned in engineering assignments that did not reflect your best work (reverse-coded)[3]
Q16d. Frequency during current school year: Turned in engineering assignments late (reverse-coded)[3]

[1] Four-item scale: 0=Not a reason, 1=Minimal reason, 2=Moderate reason, 3=Major reason
[2] Five-point scale: 0=Lowest 10%, 1=Below average, 2=Average, 3=Above average, 4=Highest 10%
[3] Four-point scale: 0=Never, 1=Rarely, 2=Occasionally, 3=Frequently. Reverse-coded for computation.

Computing the multi-item variable scores

To compute each score, item scores were summed; the scale was then normalized and multiplied by 100 for reporting.

Table 1. Post-Graduation Plans Among Junior and Senior Engineering Majors (N=2143)

Panel 1.1

	Percent marking:				
	Definitely not	Probably not	Maybe	Probably yes	Definitely yes
Engineering job	3.2	6.3	9.5	32.9	48.2
Non-engineering job	11.4	33.1	30.0	19.3	6.2
Engineering graduate school	9.9	18.3	28.9	27.1	15.7
Non-engineering graduate school	18.5	27.2	26.0	19.9	8.4

Panel 1.2

Combinations of post-graduation plans: Percent who are classified as…

Engineering focused	28.1
Non-engineering focused	6.5
Having "all other plans"	65.4

Combinations of post-graduation plans, subset analyses (n=1318): Percent who are classified as…

Engineering focused	45.7
Non-engineering focused	10.5
Having cross-field plans	43.8

In "combinations of plans", "engineering focused students" are those who marked probably/definitely yes to one or both engineering options (job, graduate school), and probably/definitely no to both non-engineering options (job, graduate school). "Non-engineering focused students" are those who marked probably/definitely yes to one or both non-engineering options, and probably/definitely no to both engineering options. "All other plans" include all other possible response combinations to the four post-graduation survey items. "Cross-field plans" include only those response combinations where students marked probably/definitely yes to at least one engineering option and one non-engineering option.

Table 2. Post-Graduation Plans Among Junior and Senior Engineering Majors, by Gender, by SES, and by Major[1]

	Percentage Among														
		Gender		Perceived family income[2]			Major								
	All students	Women	Men	Low income	Middle income	High income	AeroE	BioXE	ChemE	Civil/EnvE	CompSciE	ElecE	InduE	MechE	OthE
Full sample															
n	*2143*	*658*	*1465*	*516*	*830*	*756*	*98*	*119*	*125*	*302*	*229*	*295*	*167*	*584*	*224*
Engineering focused	28.1	24.6	29.9 [3]	27.7	32.0	24.7 [4]	26.5	21.0	20.0	41.7	30.1	31.2	9.0	27.1	29.5 [5]
Non-engineering focused	6.5	7.9	5.9	3.9	5.2	9.5	3.1	24.4	12.0	2.6	6.1	3.1	11.4	4.5	7.1
All other plans	65.4	67.5	64.2	68.4	62.8	65.7	70.4	54.6	68.0	55.6	63.8	65.8	79.6	68.5	63.4
Refined sample															
N	*1318*	*406*	*903*	*306*	*522*	*472*	*56*	*82*	*69*	*194*	*144*	*193*	*86*	*354*	*140*
Engineering focused	45.7	39.9	48.5 [3]	46.7	51.0	39.6 [4]	46.4	30.5	36.2	64.9	47.9	47.7	17.4	44.6	47.1 [5]
Non-engineering focused	10.5	12.8	9.5	6.5	8.2	15.3	5.4	35.4	21.7	4.1	9.7	4.7	22.1	7.3	11.4
Cross-field plans	43.8	47.3	42.0	46.7	40.8	45.1	48.2	34.1	42.0	30.9	42.4	47.7	60.5	48.0	41.4

[1]In "post-graduation plans", "engineering focused students" are those who marked probably/definitely yes to one or both engineering options (job, graduate school), and probably/definitely no to both non-engineering options (job, graduate school). "Non-engineering focused students" are those who marked probably/definitely yes to one or both non-engineering options, and probably/definitely no to both engineering options. "All other plans" include all other possible response combinations to the four post-graduation survey items. "Cross-field plans" include only those response combinations where students marked probably/definitely yes to at least one engineering option and one non-engineering option.

[2]The five categories in this response scale are collapsed to three for these analyses: Low income="low income" and "lower-middle income"; Middle income="middle income"; High income="upper middle income" and "high income".

[3]Women mean engineering focused < Men mean engineering focused in full sample at p<.05, in refined sample at p<.01 (independent sample t-test).
[4]Middle income mean engineering focused > High income mean engineering focused in full sample at p<.01, in refined sample at p<.01 (one-way ANOVA with posthoc pairwise comparisons).

[5]Mean engineering focused varies significantly between majors (overall ANOVA for full sample, p<.001; overall ANOVA for refined sample, p<.001). See text for more details.

AeroE=Aerospace Engineering, BioXE=BioX Engineering, ChemE=Chemical Engineering, CompSciE=Computer science in engineering, ElecE=Electrical Engineering, InduE=Industrial Engineering, MechE=Mechanical Engineering, OthE=Other Engineering

Table 3. Results of Multinomial Logit Models of Students' Post-Graduation Plans

Panel 3.1 Post-Graduation Plans: Full Sample (N=2143)	Level-1 Conditional Model		
	coefficient	se	p-value
For category 0: Non-engineering focused (reference group: engineering focused)			
Intercept	-2.50	0.42	0.000
URM women [1]	-0.95	0.65	0.143
Perceived family income (standardized)	0.07	0.12	0.561
Financial motivation (standardized)	-0.49	0.11	0.000
Intrinsic psychological motivation (standardized)	-0.98	0.10	0.000
Exposure to engineering work (standardized)	-0.38	0.12	0.002
Involvement in engineering classes (standardized)	-0.39	0.11	0.001
Participation in non-engineering activities (standardized)	0.46	0.14	0.002
GPA (standardized)	0.08	0.12	0.512
Professional/interpersonal confidence (standardized)	0.68	0.12	0.000
Aerospace engineering [2]	-0.43	0.77	0.577
BioX engineering [2]	1.44	0.42	0.001
Chemical engineering [2]	1.19	0.47	0.012
Civil/Environmental engineering [2]	-1.31	0.48	0.006
Computer science/engineering [2]	0.67	0.47	0.154
Electrical engineering [2]	0.17	0.45	0.701
Industrial engineering [2]	0.78	0.49	0.108
Other engineering [2]	0.32	0.48	0.503
Expected salary given major field and state (using median salaries from BLS occupation data, 2007) (standardized)	-0.34	0.17	0.044

Panel 3.2 Post-Graduation Plans: Refined Sample (N=1318)	Level-1 Conditional Model		
	coefficient	se	p-value
For category 0: Non-engineering focused (reference group: engineering focused)			
Intercept	-2.58	0.46	0.000
URM women [1]	-0.97	0.71	0.173
Perceived family income (standardized)	0.03	0.13	0.826
Financial motivation (standardized)	-0.57	0.12	0.000
Intrinsic psychological motivation (standardized)	-1.11	0.12	0.000
Exposure to engineering work (standardized)	-0.49	0.13	0.000
Involvement in engineering classes (standardized)	-0.40	0.13	0.002
Participation in non-engineering activities (standardized)	0.52	0.15	0.001
GPA (standardized)	0.10	0.14	0.485
Professional/interpersonal confidence (standardized)	0.73	0.13	0.000
Aerospace engineering [2]	-0.47	0.83	0.573
BioX engineering [2]	1.62	0.46	0.001
Chemical engineering [2]	1.58	0.52	0.003
Civil/Environmental engineering [2]	-1.15	0.52	0.026
Computer science/engineering [2]	0.92	0.50	0.067
Electrical engineering [2]	0.16	0.47	0.734
Industrial engineering [2]	0.53	0.53	0.323
Other engineering [2]	0.34	0.53	0.514
Expected salary given major field and state (using median salaries from BLS occupation data, 2007) (standardized)	-0.35	0.18	0.057

For category 1: All other plans (reference group: engineering focused)			
Intercept	0.97	0.15	0.000
URM women [1]	0.28	0.22	0.205
Perceived family income (standardized)	-0.02	0.06	0.692
Financial motivation (standardized)	-0.03	0.05	0.596
Intrinsic psychological motivation (standardized)	-0.30	0.06	0.000
Exposure to engineering work (standardized)	-0.06	0.06	0.302
Involvement in engineering classes (standardized)	-0.27	0.06	0.000
Participation in non-engineering activities (standardized)	0.05	0.06	0.369
GPA (standardized)	-0.18	0.06	0.002
Professional/interpersonal confidence (standardized)	0.26	0.06	0.000
Aerospace engineering [2]	0.05	0.29	0.859
BioX engineering [2]	-0.05	0.28	0.864
Chemical engineering [2]	0.27	0.27	0.327
Civil/Environmental engineering [2]	-0.73	0.18	0.000
Computer science/engineering [2]	-0.06	0.23	0.801
Electrical engineering [2]	-0.07	0.19	0.701
Industrial engineering [2]	0.67	0.30	0.027
Other engineering [2]	-0.20	0.24	0.403
Expected salary given major field and state (using median salaries from BLS occupation data, 2007) (standardized)	-0.09	0.10	0.374
Variance components			
Tau Category 0	2.84		
Tau Category 1	0.40		
Sigma-squared [3]	3.29		

For category 1: Cross-field plans (reference group: engineering focused)			
Intercept	0.03	0.18	0.870
URM women [1]	0.66	0.26	0.011
Perceived family income (standardized)	0.00	0.07	0.957
Financial motivation (standardized)	0.02	0.07	0.762
Intrinsic psychological motivation (standardized)	-0.29	0.08	0.000
Exposure to engineering work (standardized)	-0.07	0.07	0.337
Involvement in engineering classes (standardized)	-0.35	0.07	0.000
Participation in non-engineering activities (standardized)	0.08	0.07	0.252
GPA (standardized)	-0.11	0.07	0.124
Professional/interpersonal confidence (standardized)	0.46	0.07	0.000
Aerospace engineering [2]	-0.01	0.36	0.982
BioX engineering [2]	0.16	0.33	0.636
Chemical engineering [2]	0.31	0.34	0.365
Civil/Environmental engineering [2]	-0.71	0.23	0.002
Computer science/engineering [2]	0.01	0.28	0.968
Electrical engineering [2]	-0.01	0.23	0.969
Industrial engineering [2]	0.54	0.34	0.119
Other engineering [2]	-0.11	0.30	0.720
Expected salary given major field and state (using median salaries from BLS occupation data, 2007) (standardized)	-0.07	0.12	0.534
Variance components			
Tau Category 0	3.40		
Tau Category 1	0.52		
Sigma-squared [3]	3.29		

[1] Reference group: All other students

[2] Reference group: Mechanical engineering

[3] Approximation based on the standard logistic distribution where variance equals pi-squared/3.

Note: Robust standard errors could not be computed for the level-1 conditional models.

Note: Preliminary analyses were conducted testing URM Status and Gender as separate measures. Coefficients for both were nonsignificant in the full-sample model. In the refined sample model, URM Status was a positive predictor of Category 1 ("Cross-Field Plans") (b=.42, se=.19, p=.028), and Gender (0=female, 1=male) was borderline significant and negative (b=-.30, se=.15, p=.051).

Table 4. Median Salary Among States in the APPLES Institutional Sample by Occupational Category

Occupational Category	Median Salary
Computer Hardware/Software Engineers[1]	84,743
Aerospace Engineers	80,455
Electrical Engineers	79,449
Chemical Engineers	78,969
Industrial Engineers	72,019
Mechanical Engineers	71,787
Environmental Engineers	70,879
Biomedical Engineers	70,748
Civil Engineers	69,825

Source: Bureau of Labor Statistics, 2007. These occupational categories map to the focal APPLES majors in the present study. Average median salary for other occupational categories that map to smaller APPLES majors (e.g., "Marine engineers") are available on request.

[1]This category represents the aggregate of three BLS categories: Computer Hardware Engineers; Computer Software Engineers, Applications; and Computer Software Engineers, Systems Software.

Table 5. Student SES by Major and by Select Institutional Characteristics[1]

	Percentage Among			Significance tests (one-way ANOVA posthoc pairwise comparisons)[2]		
	Low income	Middle income	High income	mean low inc v mean mid inc	mean mid inc v mean high inc	mean low inc v mean high inc
n	*516*	*830*	*756*			
Major						
Aerospace engineering	3.9	5.1	4.4	ns	ns	ns
BioX engineering	4.1	4.9	6.9	ns	ns	ns
Chemical engineering	5.6	5.4	6.3	ns	ns	ns
Civil/Environmental engineering	15.3	15.3	12.0	ns	ns	ns
Computer science/engineering	13.4	10.4	9.7	ns	ns	ns
Electrical engineering	14.9	13.1	13.5	ns	ns	ns
Industrial engineering	6.4	6.7	9.7	ns	ns	ns
Mechanical engineering	27.3	29.2	25.5	ns	ns	ns
Other engineering	9.1	9.9	12.0	ns	ns	ns
Institutional characteristics						
SAT composite (math 75th+reading 75th): Quartiles						
Highest quartile (1500-1580)	12.4	13.9	28.0	ns	***	***
Second highest quartile (1290-1460)	36.6	39.3	40.5	---	---	---
Third highest quartile (1130-1250)	32.8	32.2	24.5	---	---	---
Lowest quartile (960-1100)	18.2	14.7	7.0	ns	***	***
Institutional control[3]						
Public institution	70.7	71.1	58.3	---	---	---
Private institution	29.3	28.9	41.7	ns	***	***
Percent undergraduates receiving federal financial aid: Quartiles						
Highest quartile (37-69%)	21.7	12.2	6.2	***	***	***
Second highest quartile (22-28%)	20.2	20.0	14.6	---	---	---
Third highest quartile (17-21%)	47.7	54.7	54.8	---	---	---
Lowest quartile (6-13%)	10.5	13.1	24.5	ns	***	***

Percent part-time undergraduates: Quartiles						
Highest quartile (28-44%)	26.7	18.8	8.5	**	***	***
Second highest quartile (16-26%)	32.6	35.9	31.5	---	---	---
Third highest quartile (7-12%)	17.4	23.4	30.8	---	---	---
Lowest quartile (0-3%)	23.3	21.9	29.2	ns	**	*
Percent graduate students: Quartiles						
Highest quartile (29-60%)	33.1	39.8	48.3	*	**	***
Second highest quartile (18-26%)	41.9	39.3	31.9	---	---	---
Third highest quartile (15-17%)	16.7	13.7	8.2	---	---	---
Lowest quartile (0-12%)	8.3	7.2	11.6	ns	**	ns

[1]The five categories in the SES response scale are collapsed to three for these analyses: Low income="low income" and "lower-middle income"; Middle income="middle income"; High income="upper middle income" and "high income".

[2]For institutional characteristics cut into quartiles, ANOVAs were conducted among the highest quartile and lowest quartile only.

[3]Of the 21 institutions in the APPLES institutional sample, 13 are public, 8 are private.

***p<.001 **p<.01 *p<.05

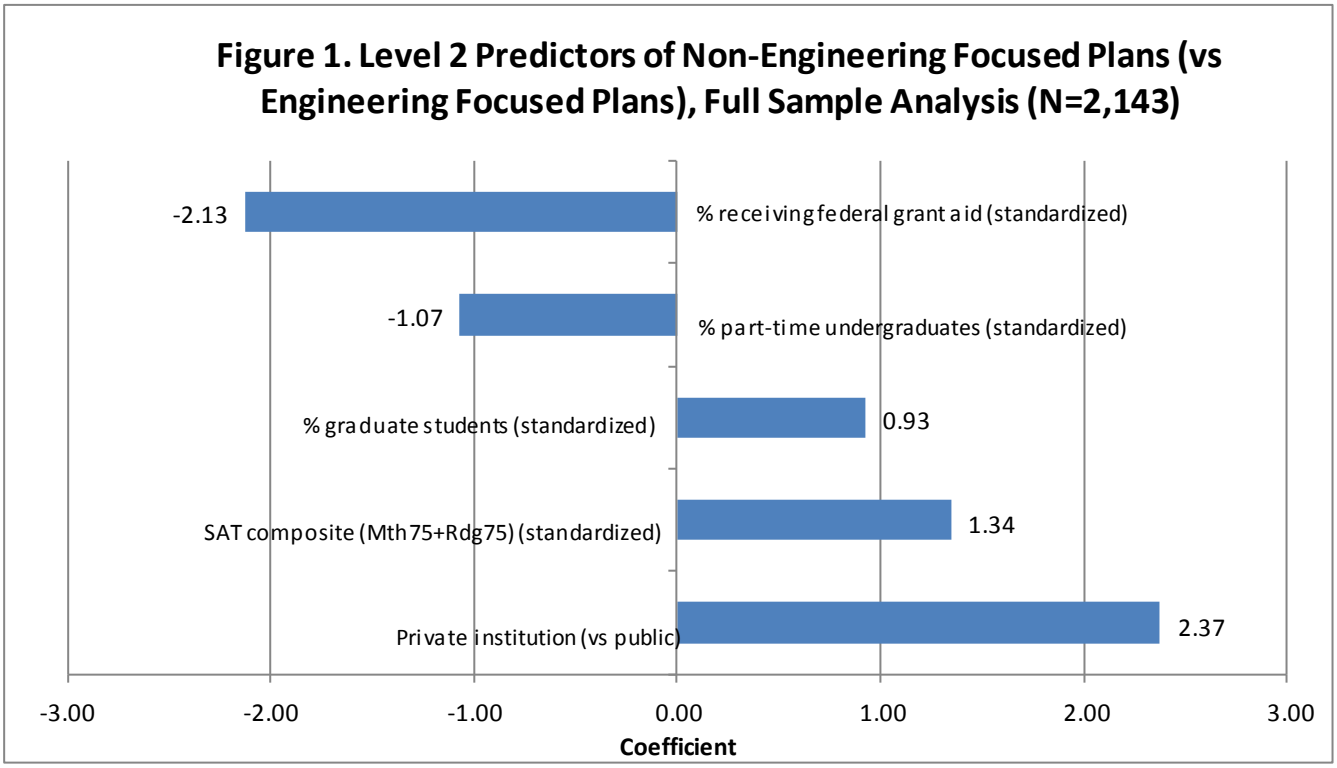
Table 6. Student Motivation to Study Engineering by Major and Gender (N=2143)

	Intrinsic Psychological Motivation (means)			Significance test for gender difference (t-test)	Financial Motivation (means)			Significance test for gender difference (t-test)
	All students	Women	Men		All students	Women	Men	
Higher rates of engineering focused plans[1]:								
Aerospace engineering	82.5	87.2	81.8	ns	58.9	45.3	61.0	ns
Civil/Environmental engineering	80.8	82.9	79.7	ns	64.4	62.8	65.4	ns
Computer science/engineering	80.5	75.0	81.9	ns	66.0	65.2	65.9	ns
Electrical engineering	82.8	87.7	81.5	*	67.5	72.3	66.2	ns
Mechanical engineering	81.4	78.9	82.1	ns	64.6	65.1	64.8	ns
Other engineering	81.5	83.4	79.6	ns	63.8	61.9	65.5	ns
Lower rates of engineering focused plans[1]:								
BioX engineering	78.2	77.4	78.7	ns	55.8	52.6	58.8	ns
Chemical engineering	77.3	75.6	79.0	ns	66.3	68.5	64.5	ns
Industrial engineering	69.7	66.1	73.2	ns	71.5	73.8	68.6	ns

Among all students, ANOVA for Intrinsic Psychological Motivation is significant at p<.001. Looking at pairwise comparisons, all means are significantly different from Industrial Engineering except for Chemical Engineering.

Among all students, ANOVA for Financial Motivation is significant at p<.001. Looking at pairwise comparisons, all means are significantly different from BioX Engineering except for Aerospace Engineering, Civil/Environmental Engineering, and Other Engineering. In addition, Aerospace Engineering is significantly different from Industrial Engineering.

[1]"Higher rates of engineering-focused plans" include those majors with 40% or more of students who report engineering focus, based on the refined sample proportions (see Table 2). "Lower rates" include those majors with less than 40%. Motivation is analyzed among students in the full sample.



Note to be placed under Figure 1: Predictors are significant at p<.05 holding all Level 1 variables constant. Due to limitations of institutional sample size (N=21), each variable was tested in a separate model. Standard errors are available on request. See Methodology for additional details.