Persistence, Engagement, and Migration in Engineering Programs

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ABSTRACT

Records from the Multiple-Institution Database for Investigating Engineering Longitudinal Development indicate that engineering students are typical of students in other majors with respect to: persistence in major; persistence by gender and ethnicity; racial/ethnic distribution; and grade distribution. Data from the National Survey of Student Engagement show that this similarity extends to engagement outcomes including course challenge, faculty interaction, satisfaction with institution, and overall satisfaction. Engineering differs from other majors most notably by a dearth of female students and a low rate of migration into the major. Noting the similarity of students of engineering and other majors with respect to persistence and engagement, we propose that engagement is a precursor to persistence. We explore this hypothesis using data from the Academic Pathways Study of the Center for the Advancement of Engineering Education. Further exploration reveals that although persistence and engagement do not vary as much as expected by discipline, there is significant institutional variation, and we assert a need to address persistence and engagement at the institutional level and throughout higher education. Finally, our findings highlight the potential of making the study of engineering more attractive to qualified students. Our findings suggest that a two-pronged approach holds the greatest potential for increasing the number of students graduating with engineering degrees: identify programming that retains the students who come to college committed to an engineering major, and develop programming and policies that allow other students to migrate in. There is already considerable discourse on persistence, so our findings suggest that more research focus is needed on the pathways into engineering, including pathways from other majors.

Keywords: engagement, persistence, migration

I. INTRODUCTION

A. Prior Research on Outcomes for Students

Those responsible for designing, maintaining, and delivering engineering education are asking questions to understand college outcomes of undergraduate engineering programs. These questions have been motivated by concerns about declining interest in studying engineering (Melsa, 2007), the continued lack of gender and ethnic diversity in the engineering population in education and practice (Chubin, May, and Babco, 2005), and the effectiveness of programs in preparing engineering graduates to take on today's engineering challenges (Lattuca, Terenzini, and Volkwein, 2006; Lattuca et al., 2006; National Academy of Engineering, 2004).

Astin's continuing research on student development in higher education, conducted with large-scale surveys of first- and fourth-year students over a forty-year time span, offers some conclusions specific to engineering. In *What Matters in College? Four Critical Years Revisited*, Astin (1993) identifies a student's major as being a highly influential environmental factor. He concludes that "engineering produces more significant effects on student outcomes than any other major field" (p. 371). Majoring in engineering was positively correlated with the development of strong analytic skills (p. 237) and job-related skills (p. 240), but was negatively correlated with overall satisfaction with the college experience, satisfaction with curriculum and instruction, and development of a diversity orientation (p. 306). This significant influence of disciplinary major on college outcomes was corroborated in *Inside the Undergraduate Experience: The University of Washington's Study of Engineering Learning* (Beyer et al., 2007), in which the significant influence of major on learning a range of cognitive skills (from quantitative reasoning skills to writing competency) is illustrated.

Much of the engineering-specific research on student outcomes focuses on finding ways to retain students in the undergraduate engineering major. Such studies seek to identify candidates with the capacity and motivation to practice engineering, as well as to improve institutional policies and instructional practices that encourage engineering students to complete the degree (Felder et al., 1998; Knight, Carlson, and Sullivan, 2007). While such studies offer valuable insights into the experience of engineering undergraduates, engineering persistence is rarely considered in the context of persistence in other majors. A notable exception is Seymour and Hewitt's (1997) significant qualitative study of why undergraduates leave the sciences in which they compare the persistence in various major groups to provide context for their results.

Seymour and Hewitt conducted a three-year study of 460 science, mathematics, and engineering (SME) students at seven institutions, investigating why students leave or persist in these majors. They studied attrition using ethnographic interviews to derive a set of testable hypotheses from student reflections, including evaluating how students weighed numerous factors in making a decision to abandon SME majors for non-SME majors or, conversely, to persist in SME majors despite challenges and setbacks. This study of SME majors found that students who switched from SME majors were not "different kinds of people" from those who continued. Switchers were not necessarily less qualified to master the necessary technical concepts, but they evaluated the SME-major academic experience as highly unsatisfactory due to their perceptions of a lack of success or dissatisfaction with the way courses were taught (or both). Both persisters and switchers reported experiencing the same problems in the educational experience, but for switchers, these problems led them to abandon the SME major. Finally, most of the factors causing students to abandon SME majors resulted from "structural or cultural sources" (e.g., inadequate teaching, excessively competitive grading systems, and a lack of identification with SME-major careers).

Adelman (1998), drawing evidence from the eleven-year college transcript history of the *High School & Beyond/Sophomore Cohort Longitudinal Study*, studied engineering undergraduate careers as well as the high school transcripts, test scores, and surveys of this nationally representative sample. Adelman introduces the idea of *curricular momentum*, which can reinforce student trajectories within engineering, establish preferred pathways for students leaving engineering, and create barriers for students who might be interested in entering the engineering field. Adelman's work demonstrates the important influence of curricular factors on how students explore and choose majors—the perception of overload, the investment in courses specific to a subset of curricular pathways, and other factors. His findings illustrate the need for enough fidelity in research to capture the subtle dimensions of navigating and defining an academic pathway.

It is important to note that these are but two studies in the larger body of research on outcomes in higher education. Questions about the outcomes of a college education have been the focus of many other studies of U.S. higher education over the last 40 years. Pascarella and Terenzini (2005) summarize literally thousands of studies of college outcomes, from cognitive skills and academic achievement to affective qualities such as attitudes, beliefs, and moral maturing. Pascarella and Terenzini also identify factors that affect these outcomes—factors that range widely and include institutional type, college major, and pedagogical approach.

Particularly relevant to the research presented in this paper are the ideas of Pace (1979) and Astin (1970a, 1970b) on college outcomes as related to what students bring to college and how they "interact" with their college. Pace introduced the idea of quality of effort as a measure of the college student experience, studying the relationship between participation and college success. Pace operationalized such measures in the College Student Experiences Questionnaire (Indiana University, 2005) that later became the basis for the National Survey of Student Engagement (NSSE) (2007), where quality of effort was replaced with the descriptor "engagement" as an indicator of the student's participation in (or exposure to) educationally effective practices. NSSE reports engagement through the use of five constructs (which they refer to as "benchmarks"): Academic Challenge, Active and Collaborative Learning, Student-Faculty Interaction, Enriching Educational Experiences, and Supportive Campus Environment.

Astin (1970a, 1970b), a contemporary of Pace, proposed what is one of the most durable and influential college impact models: the *input-environment-outcome (I-E-O)* model, which aims to be a conceptual and methodological guide to the study of college effects. "Inputs" include the demographic characteristics, family background, and academic and social experiences that students bring to college. "Outcomes" include students' characteristics, knowledge, skills, attitudes, values, beliefs, and behaviors as they exist after college. While the inputs shape some of the outcomes directly, the outputs are also affected through the institutional "Environment"—everything that happens in college that shapes the outcomes. An important aspect of the concept of institutional environment is that it goes beyond *between-institution* measures (such as institutional characteristics, curricular structure, major, and faculty make-up) to include the ways that students are involved or engaged with this environment. Astin refers to these latter measures as *individual involvement measures*; they include Academic Involvement, Involvement with Faculty, Involvement with Peers, and Involvement in Work. Cognitive outcomes in Astin's model reflect the use of higher-order mental processes (such as reasoning and logic), knowledge and skills, and academic achievement. The affective outcomes (sometimes referred to as non-cognitive outcomes) identified by Astin et al. (1967) include self-concept, identity, attitudes, beliefs, drive for achievement and satisfaction with college. The issues of engagement and the work of Pace and of Astin are addressed in significantly more detail elsewhere in this special issue (Chen, Lattuca, and Hamilton, 2008).

B. Our Research Question

Based on this prior research, our central research question is:

> *How do the persistence, engagement, and migration to other majors of students who matriculate in engineering compare to those of students of other academic majors?*

This paper examines engagement factors and educational outcomes of students in engineering majors as well as students in other fields of study, including arts and humanities, business, computer science, other science, technology, and mathematics (STM) fields, and social sciences. By considering engineering students in relation to students in other fields, we aimed to discover new insights regarding college outcomes for engineering students, the extent to which these outcomes and engagement factors are engineering-specific, and how to improve desirable outcomes and remediate undesirable ones.

Adelman's (2004) curricular momentum, described above, provides a framework for explaining one of our most interesting findings—that the rate of persistence in engineering is higher than that of other groups of majors. We build on the work of Pace and Astin by studying *educational outcomes* and *engagement* or *involvement* factors of those who study engineering compared to those who study other majors (see Tables 1A and 1B, respectively). These outcomes are measured using two extensive data sets: MIDFIELD, the Multiple-Institution Database for Investigating Engineering

1A. Educational outcomes	*1B. Engagement or involvement factors*
Choosing a major (MIDFIELD)	Active and Collaborative Learning (NSSE)
Choosing to stay enrolled at a particular university (MIDFIELD)	Course-Related Interactions with Faculty (NSSE)
Diversity (NSSE)	Enriching Educational Experience (NSSE)
Gains in Personal Development (NSSE)	Out-of-Class Relationships with Faculty (NSSE)
Gains in Social Development (NSSE)	Quality of Campus Relationships (NSSE)
Grades (NSSE and MIDFIELD)	Satisfaction and Quality of Campus Relationships (NSSE)
Gains in Practical Competence (NSSE)	Support for Student Success (NSSE)
Gains in General Education (NSSE)	Time-on-Task (NSSE)
Higher Order Thinking (NSSE)	Use of Information Technology (NSSE)
Integrative Learning (NSSE)	
Reflective Learning (NSSE)	
Satisfaction with College (NSSE)	

Tables 1A and 1B. Educational outcomes and engagement or involvement factors studied in this paper.

Development (2007) and data from the National Survey of Student Engagement (2007).

This study builds on the work of Seymour and Hewitt (1997) in four main ways. First, we use MIDFIELD to compare persistence in engineering to persistence in other fields. Second, we use data from both MIDFIELD and the NSSE to investigate the similarity of those who persist in engineering compared to those who do not and extend the work of prior studies. Third, we use an additional, smaller data set from the Academic Pathways Study to provide some insight into why persisters and switchers interpret and act on similar experiences in different ways. Finally, we use NSSE survey data to compare the experiences of engineering students to those of students in other majors.

C. A Roadmap

We first present a summary of results to give the reader a substantive overview of our major assertions. We do so to provide the reader with some *a priori* insights into the outcomes from the analyses presented. Next, in the Methods section, we describe the data sets used in our study and provide the detail necessary to establish the credibility of the findings. The evidence supporting our assertions is presented in the subsequent section, Findings. We finish with a discussion of our major conclusions and outline directions for future research.

II. SUMMARY OF RESULTS

Data for this paper derive from two extensive data sets and a third more focused data set. MIDFIELD includes institutional data for nearly 70,000 engineering students from among over 300,000 first-time students from nine institutions, in 13 cohorts studied over a 17-year period. The NSSE data include over 73,000 freshmen and seniors from institutions representing all Carnegie Basic classifications on self-reported demographic and engagement items and scales. Both databases include students majoring in arts and humanities, business, computer science, engineering, other STM (excluding computer science), social sciences, and other disciplines. Our findings from these two extensive data sets challenge prevailing notions about the engineering major and issues related to persistence and engagement. A third data set from the Academic Pathways Study begins to develop our understanding of the relationship between persistence and engagement. Our major results are:

1) Engineering Has the Highest Rate of Persistence and the Lowest Rate of Inward Migration: MIDFIELD data show that 57 percent of students who matriculate in engineering are still enrolled in engineering in their eighth semester—the highest rate of persistence of all major areas studied. Students who matriculated in engineering were also more likely to graduate from college than students of other majors. For all majors, approximately one-half of those students who switch from their original major are no longer enrolled at their original institution by the eighth semester. While persistence in engineering is similar to persistence in other majors, what distinguishes engineering from the other major groups is a very low rate of students switching from other majors into engineering. Of all the students enrolled in engineering in their eighth semester, only seven percent had migrated into engineering after having matriculated in some other major area—over 93 percent had matriculated in engineering. In contrast, other majors had large inbound migrations; by the eighth semester, all groups of majors except engineering comprise 30 percent to 65 percent of students who matriculated in another major.

2) Except for the Low Proportion of Women, Engineering Students are Demographically Similar to Other College Students: Engineering students showed little difference in demographics compared to those in other majors, with the notable exception that there is a dearth of women enrolled in these programs relative to their general presence in higher education. Our findings also show that women persist in engineering programs at rates similar to men. Few meaningful differences were observed in the matriculation or persistence rates of different racial/ethnic groups. Furthermore, persistence of women and all races in engineering is the highest compared to other majors studied. The similarity of the persistence of the majority White population and the persistence of underrepresented groups may be partially due to our choice to restrict our study population to first-time students, excluding students who transferred from another institution. Adelman (2004) finds that, in studying only students earning standard high school diplomas within a year of their anticipated high school graduation date, the differences in access rates between White and both African-American and Latino students are statistically insignificant. That is, restricting the population can restrict the range of outcomes present in that population. Since our population is restricted by the exclusion of transfer students, we might expect a similar reduction in variability. The same findings are supported by NSSE data, which show no important differences in terms of the proportions of enrollment among those in engineering compared to those in other majors in terms of race, enrollment status (full-time/part-time), first-generation college student status, citizenship, or athletic status.

3) Engineering Students Might Think Their Grades are Lower, but They Are Not: Engineering students self-report through NSSE that they are less likely to have high GPAs and more likely to have lower GPAs than students in other majors. However, results are not statistically significant using effect size calculations, and MIDFIELD data show that the relative frequencies of course grades are similar for all majors.

4) Engineering Students are Similar to Other Students in Terms of Engagement: We studied 14 dimensions of student engagement, based on item-clusters (scales) embedded in the NSSE instrument. Dimensions of student engagement included classroom engagement, faculty interaction, and institutional engagement. Using effect size calculations, we found no statistically significant difference by major in any of these areas.

5) All Students Become More Disengaged Over Time, but Non-Persisters Disengage More Quickly: The Academic Pathways longitudinal study of engineering student persistence shows that students who persist in engineering start out with a fairly low level of disengagement in both their engineering and liberal arts courses, then their level of disengagement in both types of courses increases over four years of study. The responses of non-persisters do reveal statistically significant differences compared to persisters, particularly with respect to the rate of disengagement.

NSSE and MIDFIELD data are consistent. Patterns of enrollment, engagement, and persistence of engineering majors are, in fact, similar to those of other majors. Like Seymour and Hewitt (1997), we find that students who start in engineering resemble other students in terms of their engagement in, and outcomes from, their college education. However, we have a lot more to learn about how students come to "own" a particular major. The current work shows that looking at this question for a variety of majors is likely to provide greater insights than single-field studies about the processes involved in choosing a major and how students can be better supported by institutional practices.

III. METHODS

Data for this paper come from three data sets. One is the Multiple-Institution Database for Investigating Engineering Longitudinal Development (2007). MIDFIELD comprises nearly 70,000 first-time engineering students among over 300,000 first-time undergraduates in nine institutions from 1987–2004. Because we make comparisons to national data from the Integrated Postsecondary Educational Data System (U.S. Department of Education, 2007b), we restrict our population similarly to include only students matriculating each fall and the preceding summer. While MIDFIELD also contains records for many non-first-time students, these were excluded from this study primarily because those students can differ from first-time students in many ways that are not tracked in student records. The second data set used is the National Study of Student Engagement, administered in spring 2006 (NSSE: National Survey of Student Engagement, 2007). The data from NSSE comprise over 73,000 freshmen and seniors from 185 institutions with engineering programs. We also use data from the Academic Pathways Study (APS), which comprises 160 engineering students from four institutions in the U.S. who were tracked from their first through senior years with surveys and interviews. APS explicitly explores academic persistence of undergraduates who declared engineering as their major in their first year (Sheppard et al., 2004).

MIDFIELD and NSSE data were aggregated into groups of majors to allow comparisons to other disciplinary areas while avoiding the complexity that would result from studying all possible majors separately. The groups of majors used in these studies were the same for each data set and are shown in Table 2. Major groupings are similar to National Science Foundation definitions (National Science Foundation, 1998). Computer science was separated from engineering and from science, technology, and math majors because it was not possible to determine from NSSE data if computer science students were enrolled in engineering programs.

A. MIDFIELD Data

MIDFIELD includes record data from all undergraduate, degree-seeking students at nine public universities in the southeastern United States. All institutions are doctoral granting research institutions; under the 2005 Carnegie basic classifications, two are Doctoral Research Universities, two have High Research Activity, and five have Very High Research Activity (McCormick and Zhau, 2005). For the present study, the population was restricted to include only first-time students (U.S. Department of Education, 2007a). The data for some MIDFIELD partner institutions only date to spring 2004; therefore, to study persistence of eight semesters, it was necessary to consider students matriculating in 1987–1999. Table 3 shows the distribution of students tracked in MIDFIELD by major at matriculation compared to a national sample.

Engineering students are overrepresented at the MIDFIELD institutions. In 2005, 330 institutions nationwide (out of approximately 350) reported engineering degrees awarded. Those institutions enrolled a total of 310,022 undergraduate engineering students (American Society for Engineering Education, 2005). Engineering students represented nine percent of the 3,320,249 students enrolled in all majors at those same 330 institutions (U.S. Department of Education, 2007b). The MIDFIELD institutions include six of the 50 largest U.S. engineering programs (by undergraduate enrollment), in which over 20 percent of matriculated students are in engineering. This is a population that includes approximately one-twelfth of all engineering graduates of U.S. engineering programs annually. The percentage of women and of Latinos (regardless of gender) among MIDFIELD's engineering graduates is representative of other U.S. programs. African-American students, however, are significantly overrepresented in the MIDFIELD data set, since the MIDFIELD participants include four of the top five producers of African-American engineering graduates, including two historically Black colleges and universities (HBCU). Together, all MIDFIELD schools graduate one-fifth of all U.S. African-American engineering B.S. degree recipients each year. These ratios are computed from the most recent year in the data set; the

Term	Definition
A&H	Arts and Humanities: History; Communications, Journalism and Related Programs; Communications Technologies and Support Services; Foreign Languages, Literature and Linguistics; Law, Legal Services and Legal Studies; Liberal Arts and Sciences; General Studies and Humanities; Multi/Interdisciplinary Studies; Philosophy and Religion; Theological Studies and Religious Vocations; Visual and Performing Arts.
Bus	Business: Economics, Management, Marketing and Related Support Services.
Comp Sci	Computer Science: Computer and Information Services and Support Services. Computer Science is treated as a special case because it exists in some institutions as an engineering program, in others not, and in some, both.
Engr	Engineering.
Other	Other: Natural Resources and Conservation; Engineering Technology; Family and Consumer Sciences/Human Studies; Law, Legal Services and Legal Studies; Library Science; Military Technologies; Parks, Recreation, Leisure and Fitness Studies; Science Technologies/Technicians; Construction Trades; Mechanic and Repair Technology; Precision Production Trades; Health Professionals and Related Clinical Sciences. Note: "Other" was not included in NSSE analyses.
Other STM	Other Science, Technology, Mathematics (STM excluding Comp Sci): Agriculture, Agricultural Operations and Related Sciences; Architecture and Related Services; Biological and Biomedical Sciences; Mathematics and Statistics; Physical Sciences.
Soc Sci	Social Sciences: Area, Ethnic, Cultural and Gender Studies; Education (not included in NSSE analyses); Political Science, Psychology, Protective Services; Public Administration and Services; and Social Sciences.
Not included	Basic Skills; Citizenship Activities; Health-related Knowledge and Skills; Interpersonal and Social Skills; Leisure and Recreational Activities; Personal Awareness and Self-improvement; Dental, Medical and Veterinary Residency Programs.

Table 2. Definitions of groups of majors used in this paper.

Population	A&H	Bus	Comp Sci	Engr	Other	Other STM	Soc Sci	Un-declared	TOTAL
MIDFIELD First-time matriculates 1987-1999	23,382	37,250	10,067	69,776	17,588	44,800	36,199	71,706	310,768
% of MIDFIELD first-time matriculates	8%	12%	3%	**22%**	6%	14%	12%	23%	100%
Enrollment at 330 schools reporting engineering graduates				310,022					3,320,249
% of total enrollment at schools reporting engineering graduates				**9%**					

Table 3. MIDFIELD and national data: Number of students by major.

exact percentages vary from year to year (American Society for Engineering Education, 2005).

Table 4 outlines study variables and definitions important for understanding MIDFIELD data.

The various assumptions of the Pearson chi-square are satisfied by the MIDFIELD data: our study uses whole-population data, sample sizes and cell sizes are large, and observations are independent and have the same underlying distribution. The use of

Term	Definition
Gender	Female or Male
Race/Ethnicity	African-American/Black, Asian, Hispanic/Latino, International, Native American, White
CIP	Classification of Instructional Programs: taxonomy of titles and descriptions of primarily postsecondary instructional programs, assigned by the National Center for Educational Statistics.
Semester	Fall and Spring terms in a semester system each count as one (1) semester. Combined full-summer terms count as 0.67 of a semester. Separate Summer 1 and Summer 2 terms each count as 0.33 of a semester. Fall, winter, spring, and summer terms in a quarter system each count as 0.67 of a semester.
Matriculation major	The academic discipline in which the student first enrolled at the institution.
Major at eight semesters	The academic discipline in which the student was enrolled during the eighth semester after matriculation. These enrolled semesters need not be continuous, and semesters in which a student was not enrolled at their home institution are not counted.
PG8	Persistence in a particular group of majors to the eighth semester.
PU8	Persistence in the university where a student matriculated (in any major) to the eighth semester.
TOLEDO	The "destination" of students for whom the real destination is unknown. This term is used to describe a student who drops out of the database without receiving a degree, or a student who is otherwise untraceable in the system. This may be because he or she transferred into another institution, has left higher education entirely, or has left temporarily and not returned. 'TOLEDO' is an acronym for "Trajectory of Leaving Education, Destination Obscure." These students are commonly described as having "gone to TOLEDO."

Table 4. Definitions of terms used in this paper.

whole-population data eliminates the need for inference; all differences are real, even when these differences are not practically significant. For example, the difference between 48 percent and 49 percent is a measurable difference, but the difference between these two numbers will not be meaningful or important in a practical sense. *For this reason, we focus on meaningful differences as opposed to statistical differences.* Exactly what is "meaningful" is subjective and is influenced by context.

Analyses of MIDFIELD data in this paper focus on persistence in a particular group of majors to eight semesters (PG8) and persistence in the university to eight semesters (PU8). Using these benchmarks enabled us to include more cohorts in the analyses because it does not require as many semesters to study a cohort as computing a six-year graduation rate, yet it still captures an accurate description of student patterns of persistence. Approximately 90 percent of MIDFIELD students in all majors in cohorts from 1987–1997 graduated in the major in which they were enrolled in their eighth semester (total population data). Nevertheless, persistence to eight semesters does not ensure graduation and differences by race and gender may accrue beyond the eighth semester.

B. NSSE Data

With the generous cooperation of the National Survey of Student Engagement, we used spring 2006 NSSE data to compare the perspectives and reported engagement of engineering students to those of non-engineering students. The NSSE was "designed to assess the extent to which students are engaged in empirically-derived, effective educational practices and what they gain from their college experience" (NSSE: National Survey of Student Engagement, 2007). The survey contains 85 questions that pertain to student engagement. Students are asked about their instructional experiences, their social experiences, and overall educational outcomes. Students are also asked to estimate the number of hours they spend engaged in school-, non-school-, family-, work- and extracurricular-related activities each week, which we refer to as *time-on-task* variables. Finally, students are asked about *enriching educational experiences* in which they have participated or plan to participate in before graduation. For this study, we used conceptually related items with high reliability to form 14 scales relevant to college environment and outcomes. Reliability of scales ranged from 0.45 to 0.89 with the median reliability, for both freshmen and seniors, of $\alpha = 0.71$.

In 2006, NSSE collected data from 131,256 freshmen and 128,727 senior students who were randomly sampled from 534 four-year colleges and universities in the U.S. and Canada. The average institutional response rate was 39 percent. NSSE schools closely mirror the profile of higher education institutions nationally in terms of Carnegie Classifications, geographical distribution, and population concentration (e.g., urban, rural, etc). Furthermore, demographic characteristics of NSSE respondents (i.e., gender, race, citizenship,

Carnegie Classification (BASIC, 2005)	A&H	Bus	Comp Sci	Engr	Other STM	Soc Sci	TOTAL Raw	TOTAL % Raw
DocRes RU-VH	1,294	1,188	145	1,195	1,633	1,366	**6,821**	**9.3%**
DocRes R-UH	1,742	1,739	388	2,221	1,958	1,949	**9,997**	**13.7%**
DocRes DRU	1,298	951	171	161	806	1,205	**4,592**	**6.3%**
Master's L	4,024	3,895	721	1,213	3,677	4,311	**17,841**	**24.4%**
Master's M	2,839	1,942	281	628	2,303	2,157	**10,150**	**13.9%**
Master's S	797	559	107	62	710	859	**3,094**	**4.2%**
BAC AS	3,890	1,517	343	395	3,896	4,055	**14,096**	**19.2%**
BAC Diverse	800	805	175	413	678	812	**3,683**	**5.0%**
Other	919	600	179	600	431	234	**2,963**	**4.0%**
TOTAL Raw	**17,603**	**13,196**	**2,510**	**6,888**	**16,092**	**16,948**	**73,237**	**100%**
TOTAL %	**24.0%**	**18.0%**	**3.4%**	**9.4%**	**22.0%**	**23.1%**	**100%**	**100%**

Table 5. NSSE data: Number of freshmen and seniors by major and Carnegie Classification.

and enrollment status) are representative of the demographic characteristics of NSSE institutions and higher education institutions nationwide.

NSSE data used for this study were limited to U.S. institutions that offered programs in both engineering and in non-engineering areas. As a result, data for this study comprise over 73,000 individuals from 185 institutions, approximately half of all engineering institutions (American Society for Engineering Education, 2005). The sample includes multiple institution types, as categorized by the 2005 Carnegie Basic Institutional Classifications (McCormick and Zhau, 2005), and includes freshmen and senior students majoring in arts and humanities, business, computer science, engineering, (non-engineering) science, technology and math, and social sciences (see Table 5).

The proportion of students surveyed in each major group was similar across majors with regard to ethnicity (with one exception, discussed below), U.S. citizenship, first-generation college student status, and college athlete status. Significant differences emerged in the area of gender. Engineering students (as well as computer science students) are much more likely to be male than students who major in arts and humanities, business, science, technology, and math, or social science. While women make up only about 20 percent of the population of freshmen and senior Engineering and Computer Science majors surveyed, they compose between 55 percent and 70 percent of those surveyed in all other majors.

Descriptive statistical analyses (i.e., frequencies, means, standard deviations), as well as chi-square analyses and analyses of covariance (ANCOVA) were conducted on demographics and scales. Scales are clusters of items that are conceptually related and that also have respectable Cronbach alphas (Pike, 2006). Table 6 shows the Cronbach alpha (α) coefficients for the NSSE scales used in this study. Chi-square analyses were run to determine whether statistically significant relationships existed between students' majors and various demographics. ANCOVAs were employed to determine if there were mean group differences for the various college majors on the student engagement measures, after adjusting for the differences associated with the demographic variables (covariates). By having covariates in the model, the sensitivity of the test of college major was increased, since the error term was reduced. Additionally, this process served as a statistical matching procedure, since students could not be randomly assigned to majors (Tabachnick and Fidell, 2001).

C. APS Data

The Academic Pathways Study (APS), part of the NSF-funded Center for the Advancement of Engineering Education, addresses questions about undergraduate student experiences and decisions to pursue an engineering degree. The relationships between persistence and development of skills and knowledge, self-perceptions, and perceived need for particular work-related skills are explored (Sheppard et al., 2004). One component of the APS is a longitudinal study in which forty students from each of four institutions (two DRU-VH and two DRU-H, one of which is STEM dominant) were followed from the freshman through the senior year to learn about student experiences and motivations, particularly as they relate to persistence in engineering. These 160 students participated in surveys, engineering activities and interviews. The Academic Pathways Study is described in greater detail elsewhere (Clark et al., 2008; Sheppard et al., 2004).

Specifically, we used results from the Persistence in Engineering (PIE) survey administered as part of APS. The PIE survey was designed to identify and characterize correlates of academic persistence in engineering education in a longitudinal context, and to broaden our understanding of how students navigate their education and form identities as engineers (Eris et al., 2005, 2007). Academic engagement is one of the several proposed correlates of persistence being investigated. The survey was administered to the APS "Longitudinal Cohort," which in some publications is referred to as "cohort 1" (Clark et al., 2008).

One of the engagement variables measured with the PIE instrument is "academic disengagement," which reflects the frequency of events signaling disengagement from engineering and non-engineering courses. These events were phrased as separate survey questions and include not attending class, being late to class, turning in homework late, and turning in homework that did not reflect

Scale	Freshman (α)	Senior (α)
Outcome Scales		
Diversity: Having serious conversations with those of differing political, religious, ethnic backgrounds; encouraging contact with those who have different beliefs and backgrounds.	0.65	0.65
Gains in General Education: Writing and speaking effectively, analyzing and thinking critically, "have you received a broad, general education?"	0.83	0.84
Gains in Personal and Social Development: Developing values and ethics, appreciation of ethnic differences, spiritual connectedness, community and civic engagement.	0.89	0.89
Gains in Practical Competence: Acquiring job- or work-related skills, use of technology, working with others, analyzing and solving real-world problems.	0.81	0.80
Higher Order Thinking: Higher order of Bloom's taxonomy: synthesizing, analyzing, judging, applying.	0.81	0.82
Integrative Learning: Integrating material across courses, including diverse perspectives, discussing ideas with faculty and other students.	0.69	0.71
Overall Satisfaction: Assessing one's undergraduate experience overall, "if you were starting over, would you choose this institution?"	0.75	0.79
Reflective Learning: Considering alternative points of view/others' perspectives, changing one's perspective on an issue.	0.79	0.80
Engagement Scales		
Active and Collaborative Learning: Assessing class participation, collaboration with classmates, community-based experiences.	0.64	0.65
Course-Related Interactions with Faculty: Discussing grades, readings, and academic performance with faculty.	0.63	0.65
Out-of-Class Relationships with Faculty: Advising by faculty, research or other non-course related experiences.	0.45	0.58
Satisfaction and Quality of Campus Relationships: Assessing relationships with students, faculty, administrators, advisors.	0.71	0.68
Support for Student Success: Supporting academic, non-academic, and social needs.	0.76	0.76
Use of Information Technology: Using electronic media to complete assignments, using email.	0.52	0.55

Table 6. Internal consistency reliability coefficients for scales for freshmen and seniors.

best work. This variable was adopted from the Your First Year in College 2003 survey (University of California Los Angeles, 2007).

The survey questions measuring the disengagement variable were asked twice, once for engineering courses and again for liberal arts courses. Students who matriculated in engineering and were still studying engineering during their eighth semester in college were termed "persisters". Students who were initially considering majoring in engineering and taking engineering-related courses but who eventually decided to pursue another major were termed "non-persisters," and are further categorized by the semester in college in which they last studied engineering. Their decision not to study engineering was documented mainly through exit interviews. For those non-persisters who left the study without completing an exit interview, academic transcripts were examined to verify the declaration of a non-engineering major. For instance, the "Sem3 NP" category would refer to the group of students in the study who decided to no longer study engineering after their third semester in college. After excluding students who exited the study for other or unknown reasons, the subject pool consisted of 108 Ps, 11 Sem2 NPs, five Sem3 NPs, 16 Sem4 NPs, and two Sem6 NPs. There were no Sem5 NPs. The Sem6 NPs are not included in this analysis as there are only two data points.

D. Limitations

In spite of the large data sets used, there are limitations to the resulting findings. The MIDFIELD data are largely regional. Further, whereas MIDFIELD tracks approximately one-twelfth of students enrolled in engineering programs, the MIDFIELD institutions are only nine out of 375 institutions accredited to grant engineering degrees (ABET, 2008). So, while students in the MIDFIELD population may be representative of U.S. engineering students, particularly students at larger research institutions, they are not representative of the diversity of institutions in the United States. Generalizations about Hispanics, Asians, and Native Americans are particularly limited because those populations tend to be concentrated in few of the nine institutions in the data set.

NSSE data are limited by lack of institution-level data, which were not available for the analysis undertaken for this paper. As highlighted below, we understand that institutional factors can strongly influence the outcomes discussed. The generalizations drawn about our data as a whole are mediated by factors at individual institutions.

Whereas NSSE contains data on students' self-reported grades and MIDFIELD contains data on students' actual grades, the more important question with respect to student decision-making in changing majors is likely to be student perceptions of the grades in other majors, and no such data were available.

IV. FINDINGS REGARDING PERSISTENCE, ENGAGEMENT, AND HOW THEY ARE RELATED

A. The Question of Persistence (MIDFIELD)

1) Where do Students Go After Matriculation?: Nearly 60 percent of students matriculating in engineering at the MIDFIELD institutions are still enrolled in engineering in their eighth semester (PG8, engineering). Table 7 summarizes raw numbers of students who matriculate into various majors (first column of numbers), the number of those who remain in the same major group through the eighth semester (second column of numbers), the total enrolled in each major group at eight semesters (including those who switched into each major group from another one, third column of numbers), and the percentage persisting to eight semesters in each major group (the second column of numbers divided by the first column).

Our figures for engineering are consistent with national averages, as Seymour and Hewitt report (1997). Seymour and Hewitt also provide comparison data for other disciplines, finding four-year persistence rates of 40 percent in STM, and 70 percent in arts, humanities, and social sciences. No more recent source could be found that examined persistence rates in such a wide range of major groups.

Note that our approach is subtly different from the four-year persistence rates Seymour and Hewitt report. As described in detail in the Methods section, our persistence rates do not count non-enrolled semesters as "lost time." More notably, Seymour and Hewitt group arts and humanities and the social sciences together. In Figure 1, which is discussed in detail below, we observe a lower persistence rate when we study arts and humanities as separate from social sciences. This is partly explained by the fact that 10 percent of students in arts and humanities switch into social sciences, and 10 percent of those who matriculate into the social sciences switch into arts and humanities—grouping the two types of majors as Seymour and Hewitt do obscures the switching patterns of each population independently.

The current study presents more detail regarding the persistence patterns of students in engineering compared to those of other groups of majors. Figure 1 summarizes the persistence in a group of majors to eight semesters (PG8), the persistence in the matriculating university to eight semesters (PU8), and the destination majors of switching students by the eighth semester for students from all matriculation major areas.

The x-axis in Figure 1 is categorical, defining the population included in each column—the population that matriculated in the discipline group labeled below the column. Reading up the column identifies where those students end up by the eighth semester. The first destination is always the disciplinary group in which the population matriculated so that the bottom line shows the rate of persistence in each major grouping to eight semesters (PG8). The discipline groups on the x-axis are in descending order of PG8.

Persistence in major group at eight semesters (PG8) ranges from 38 to 57 percent. By this measure, engineering has the highest persistence (57 percent), slightly higher than business (55 percent). More notably, engineering's nearest cousins, computer science and other STM, are at the other end of the spectrum with PG8 of 38 percent and 41 percent, respectively. Students of course cannot remain in an "undeclared" status indefinitely, so PG8 for students matriculating in that status must be zero.

Above the PG8 line (again in each column) are the other destination major groups to which at least three percent of students in a matriculated discipline migrate, stacked in descending order of the

Major group (in decreasing order of PG8)	Matriculated in major group	Students enrolled in same group in the eighth semester	Total enrolled in each group at eight semesters	Persistence in group to eighth semester (PG8)
Engr	69,776	39,897	43,086	57%
Bus	37,250	20,576	45,911	55%
Soc Sci	36,199	18,400	49,227	51%
A & H	23,382	11,664	30,932	50%
Other	17,588	7,748	22,085	44%
Other STM	44,800	18,383	31,135	41%
Comp Sci	10,067	3,837	7,116	38%
Undeclared	71,706	NA	NA	NA

Table 7. Persistence and total enrollment in various major groups to the eighth semester, MIDFIELD data set, 1987–1999 cohorts.

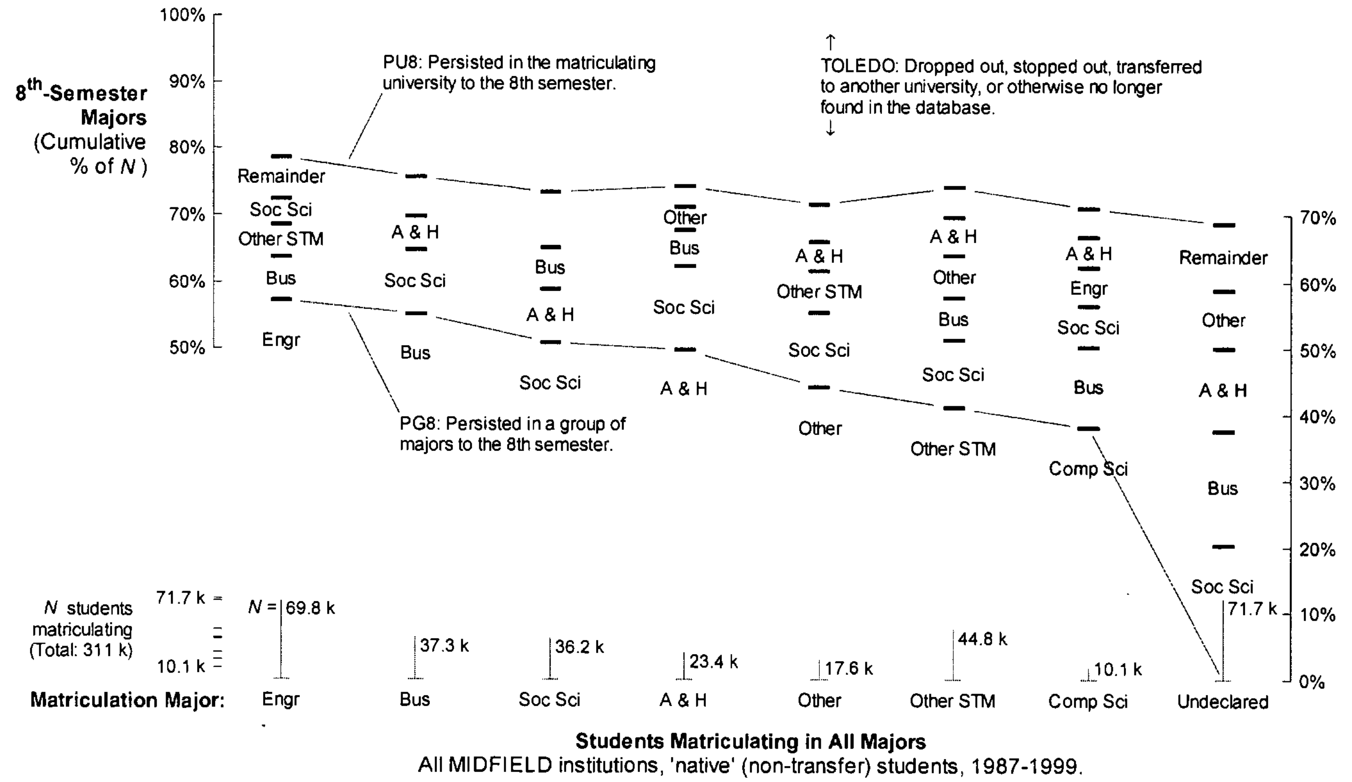


Figure 1. MIDFIELD Persistence Chart: Outcomes at eight semesters for students matriculating in various major groups, 1987–1999.

number of students following each path. Rounding out that region of the graph is the remainder—the aggregate of all the students going to discipline groupings that received fewer than three percent. Some observations of interest from this part of the graph are:

- Business is the most common destination for students switching out of engineering, but other STM, social science, and arts and humanities are nearly as common.
- Arts and humanities and social sciences each attract three percent or more of the students matriculating in each of the other groups of majors, and business attracts three percent or more of all but the "other" group of majors.
- Engineering attracts a noticeable fraction of students only from computer science.
- Students who matriculate as "undeclared" do not select STEM fields (engineering, computer science, or other STM) in significant numbers. This is particularly important, as the undeclared population is the largest.

A helper line is provided to highlight PU8, the cumulative percentage of students matriculating in each disciplinary group that persist (in any major) at the university until the eighth semester.

Above the PU8 line is, in all cases, the fraction of students matriculating in each major group who have not persisted for eight semesters at the institution where they matriculated. We cannot say that these students have left higher education or have even left their original major; all we can say is that we are unable to track them. To protect the identity of students in our data set, we are not even able to track students who transfer from one MIDFIELD institution to another.

We find that PU8 is notably more stable than PG8, ranging between 69 percent and 79 percent, and generally follows the same rank order as PG8. As with PG8, PU8 is highest among those who originally matriculate in engineering. At the bottom of the graph, proceeding from the categorical axis that shows each matriculation major group, there are small bars that show the relative size of each population. The specific number of students (N) is shown and matches the second column of Table 7. At the bottom left, a distribution of the population in the various major groups takes the place of a traditional axis frame. MIDFIELD data show that the values of PG8 and PU8 shown in Figure 1 (persistence in major and persistence at a particular university aggregated over all institutions) have fluctuated less than five percent in the 13 years of this study, in spite of much greater fluctuations in enrollment during that time. We also note that that nearly one-half the students switching from each of the major groups ends up in TOLEDO (see definition in Table 4) by the eighth semester (of engineering students, e.g., 21 percent are lost to TOLEDO, out of 43 percent who leave engineering).

2) Where Do Students Come from Who Have Been Enrolled Eight Semesters?: Reversing the axes of Figure 1 creates a new perspective, one that reveals where students came from who have been enrolled eight semesters. The population in the columns of Figure 2 is different from the population in the columns of Figure 1. In Figure 2, the population is the total number of students enrolled in each major group in their eighth semester, regardless of whether those students matriculated in that major group. The reversal of perspective from Figure 1 to Figure 2 is modeled after the work of Donaldson and Sheppard (2007), who explored students migrating into engineering. They chose the word "migrating" to capture the idea that students move from one area of interest to another over time.

The lower line now represents the percentage of students enrolled in the eighth semester in a particular major group who

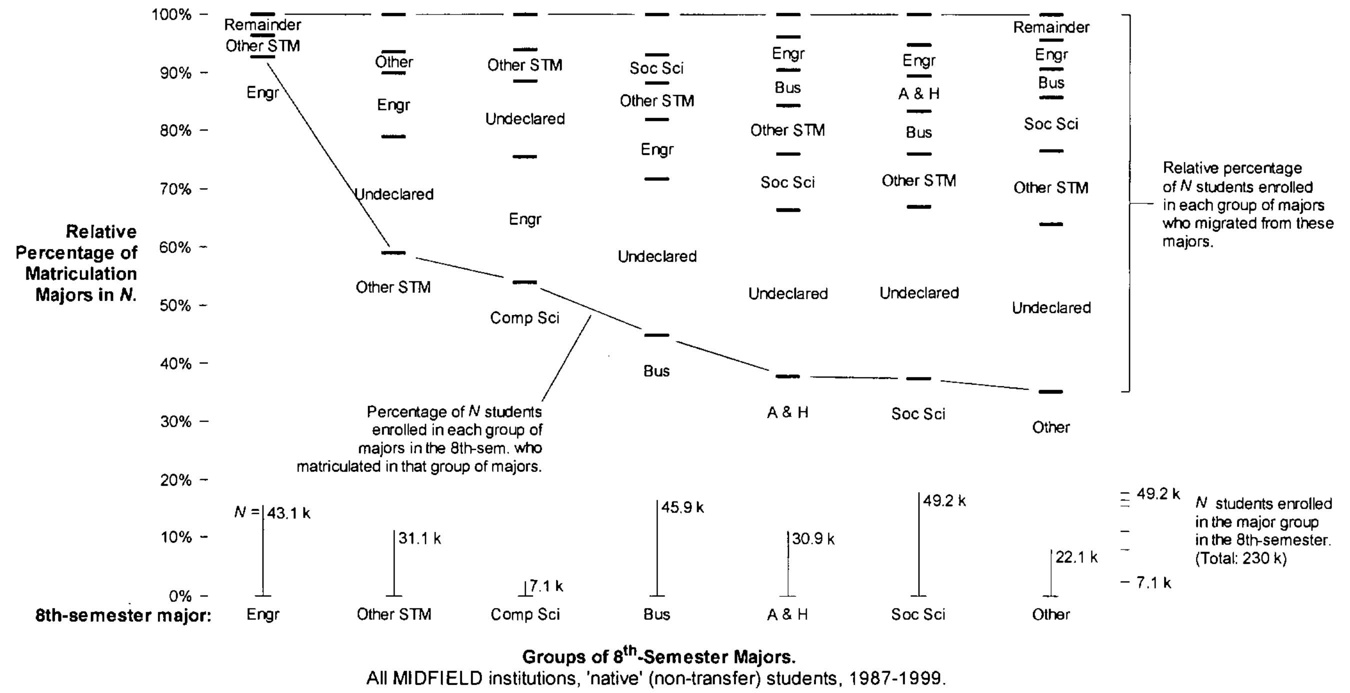


Figure 2. MIDFIELD migration chart: The matriculation major of students in various major groups in the eighth semester.

matriculated into that same major group. This highlights a real challenge faced by engineering schools and departments. Although engineering has the highest rate of persistence, it has the lowest rate of affinity for students matriculating in other major groups. The first column shows students enrolled in the engineering major group in the eighth semester and where they matriculated.

- Nearly 93 percent of students enrolled in engineering after eight semesters had matriculated in engineering. This makes engineering very distinct from other groups of majors for which the same fraction ranges from 35–59 percent.
- The other technical fields, computer science and other STM, attract over 40 percent of their eighth-semester student population from other majors.
- Whereas the number of students who matriculated as undeclared who were attracted to other STM and computer science was less than three percent of the large undeclared population, those students comprise a noticeable percentage of those enrolled in other STM and computer science in the eighth semester. Again, engineering does not attract a noticeable population of undeclared students.
- All other groups of majors attract engineering students in noticeable numbers.

A brief review indicates that various measures of persistence and migration do not vary much more than five percent by race/ethnicity or gender. Limitations on the scope of this work prohibited a more comprehensive analysis and these issues will be revisited in future work.

B. The Question of Engagement

Analyses of the NSSE data found results similar to those from the MIDFIELD data. Demographic variables included: gender, enrollment status (full-time, part-time), race/ethnicity, citizenship, first generation of family to attend college, and student athlete status. The population studied in the NSSE data was described earlier (Table 5). Consistent with the results from prior research, engineering students (as well as computer science students) were much more likely to be male than students who major in arts and humanities, business, and other STM. Conversely, the arts and humanities majors comprised more female students than males.

1) NSSE Outcome and Engagement Scales: As discussed earlier, student engagement and outcomes were determined by a series of 14 scales (eight outcome and six engagement scales), which are enumerated in Table 6. Scales were intended to capture various facets of student engagement pertaining to course experiences, extracurricular activities, faculty interaction, and institutional-level environment. A series of ANCOVAs was employed in which the independent variable of interest was college major in each case, and the covariates were gender, first generation college or not, enrollment status (part- or full-time), race/ethnicity, athlete status, and self-reported grades.

Effect sizes (partial η^2) are considered small if less than 20 percent of the variance is explained, medium if approximately 50 percent is explained, and large if more than 80 percent is explained (Stevens, 1999). In this study, effect sizes were remarkably low. The largest effect size found in this study was partial $\eta^2 = 0.05$, meaning that only five percent of the variance in the adjusted Dependent Variable (DV) score (gains in practical competence) was associated with college major (for seniors). Many of the effect sizes on the student engagement scales were zero or close to zero, indicating that there was no relationship between college major and many of the student engagement and outcome scales.

Follow-up analyses using OLS linear regression (comparing engineering majors to other STM, computer science, and other majors) confirmed effect size calculations. The areas of student engagement that were most related to college major (with engineering being the reference variable) were out of class interactions with faculty (seniors only), reflective learning, and integrative learning (all lower for engineers), and gains in practical competence for freshmen and seniors (higher among engineers). Beta weights for engineering majors versus the others for these highest associated student engagement variables ranged from $\beta = (\pm)\ 0.117-0.260$, which are relatively low. The overall R-squared associations, for freshmen and seniors, ranged only from $R^2 = 0.031-0.084$—near zero—and the majority of the variance in these student engagement dependent variables was accounted for by the demographic covariates.

One potential explanation for the lack of observed differences could be the low-levels of some of the scales. However, even those scales with high-reliability revealed extremely low effect sizes, and some scales with low reliability evidenced higher effect sizes than those with higher reliabilities. No evidence was observed to suggest that higher reliabilities among some of the scales would have appreciably increased effect size, certainly not to levels of $\eta^2 = 0.20$. It could be argued that NSSE is a measure of engagement at the institutional level, not at the level of individual major. However, we would expect the NSSE scales to reflect students' experiences in their courses and with their faculty, which likely vary by department. Some scales more clearly focus on institutional effects (e.g., gains in general education, use of information technology, and quality of campus relationships), and a lack of variance by major on these variables might be expected. Scales that focus on specific, course-related experiences (e.g., reflective learning, active and collaborative learning, course-related interactions with faculty and out-of-class relationships with faculty), however, would be expected to show variation by major, if such variation existed. The absence of disciplinary variation in these scales is, therefore, unexpected.

We urge readers to keep in mind that we can make no inference about the quality of interactions for variables that ask students to self-report frequency of behaviors related to engagement (e.g., faculty interaction). We also cannot make inferences about the nature or frequency of experiences regarding variables that have to do with quality of experiences (such as campus relationships and overall satisfaction). Certainly students in different majors have qualitatively distinct experiences based on class-sizes, structure of the major, and content.

2) Time-on-Task: The results of time-on-task analyses indicate that engineering students spend time in ways similar to other students in other majors. Engineering students did report spending more time each week preparing for class. Among seniors, engineering was the only major for which the median score fell in the 16–20 hour per week range, compared to 11–15 hours for all other majors. Senior engineers were the most represented group in the 30+ hour category. Yet, compared to other majors, these differences were practically non-significant statistically (OLS linear regression: $R^2_{\text{fresh}} = 0.064$; $R^2_{\text{seniors}} = 0.057$; beta weights near 0).

Engineering and other STM students participated slightly more frequently than students in other majors in co-curricular activities (including student organizations) campus publications, student government, fraternities or sororities, and intercollegiate or intramural sports than students in other majors. Approximately 34 percent of engineering and other STM students (compared to 30 percent of all others) participated "1–5 hours per week" in such activities. Engineering and other STM students were highest in the "6–10 hours per week" range (approximately 15 percent of freshmen and seniors reported participating this much) and were comparable to other majors in time periods from "11–30 hours per week," except computer science majors who were highest in zero hours and lowest in all other categories. Nearly 50 percent of computer science students reported zero hours of involvement in such activities, compared to 30 percent engineering and other STM majors and 35 to 45 percent among other majors. Nevertheless, these differences, while interesting, are not statistically meaningful, as reflected in linear regression analyses, which were all non-significant and are summarized in Table 8.

Engineering students did not differ appreciably from students in other majors in their on-campus employment, time spent commuting to class, or relaxing and socializing. Engineering students were similar to other STM and social science majors in terms of off-campus work. Between 70–75 percent of freshmen and 50–55 percent of seniors in these majors did not work off campus, while

NSSE Time-on-Task Variables	R^2 Freshmen	R^2 Seniors	NOTES DV=Dependent Variable
Hrs/wk working for pay off-campus	0.134	0.151	R-squared is explained by strong association between DV and covariates: full-time student and first-generation student. Being an engineering major did contribute for seniors, but the explanatory value remains low ($\beta = 0.130$).
Hrs/wk participating in co-curricular activities	0.260	0.223	R-squared is explained by strong association between DV and covariate: being an athlete.
Hrs/wk providing care for dependents living with you	0.125	0.132	R-squared is explained by strong association between DV and covariates: full-time student and first-generation student

Table 8. NSSE time-on-task variables that evidenced the highest R-squared in linear regression.

approximately 65 percent of business and computer science freshmen and 35–43 percent seniors did not work off-campus. Also, a slightly larger percentage (68–73 percent) of seniors majoring in engineering, social sciences, and arts and humanities reported zero hours caring for dependents compared to 60–65 percent of students in computer science and business majors reporting zero hours. Five percent of engineering and other STM seniors reported caring for dependents living with them for 30+ hours per week, compared to 10 percent of students in other majors.

In OLS linear regression analyses, the *R*-squared values for scales as dependent measures ranged from $R^2 = 0.009$ to $R^2 = 0.260$. Table 8 shows the *R*-squared values for scales that evidenced the highest associations. Beta-weights for all but two of these variables (engineering compared to other STM, computer science, and others) are near zero (range: $\beta = -0.081$ to $+0.056$). The highest beta-weights were for seniors on the items *hours working off-campus* ($R^2 = 0.151$; $\beta = 0.061$ to 0.130) and *hours preparing for class* ($R^2 = 0.057$; $\beta = -0.081$ to 0.219). Only in the case of *hours working off-campus* was major a contributing factor, but minimally. Slightly higher beta-weights are explained by covariates, including whether students attend full- or part-time (more students in engineering are full-time compared to students of other majors), and whether a student is first-generation to college or a student athlete (both of which are less likely to be true for engineering students than for other majors). In short, while statistical significance exists among most associations tested, the associations are very low and the explanatory value of those associations is minimal. Students do not differ in appreciable ways on these items based on their major.

3) Enriching Educational Experiences: Student self-reports regarding educationally enriching experiences yielded some unexpected responses.

- About 60 percent of students in engineering, other STM, and social sciences completed a practicum- or internship-type experience, compared to approximately 45 percent for other majors. A larger percentage of engineering majors, compared to all other majors, finished a culminating senior experience, such as a capstone course, senior project or thesis, or comprehensive exam; about 50 percent of seniors in engineering report having completed a capstone experience, compared to 40 percent or less for other majors (while a larger percentage of seniors might be expected, it is noted that some "seniors" respond to the NSSE before they complete the culminating design experience required by ABET engineering accreditation).
- Engineers were comparable to other STM, business, and social sciences in terms of their involvement in planned learning communities or cohort programs (20–25 percent), with only computer science showing reduced participation in such programs (17 percent).
- Engineering students were in the middle of the pack in terms of their involvement in community and volunteer service (59 percent); higher than computer science and business (44 percent and 56 percent, respectively) but lower than arts and humanities and social sciences (60 percent and 69 percent, respectively).
- Among seniors, 25% of engineering majors participated in a research project with a faculty member outside the regular curriculum. This was higher than business (12%), computer science (19%), and arts and humanities (20%). It was lower than those majoring in other STM (39%) and comparable to those in social sciences (26%).
- In contrast to these results, a substantially smaller proportion of engineering students had taken a foreign language course (24 percent), compared to over 52 percent for other STM, 31 percent in computer science, 35 percent in business and about 58 percent for social sciences and arts and humanities. Engineering students also evidenced lower participation in study abroad programs, with only 11 percent participating, compared to 17–28 percent for all other majors, except computer science (10 percent). Engineering (15 percent) and business students (14 percent) created self-designed majors less frequently than those in other majors (22–29 percent).

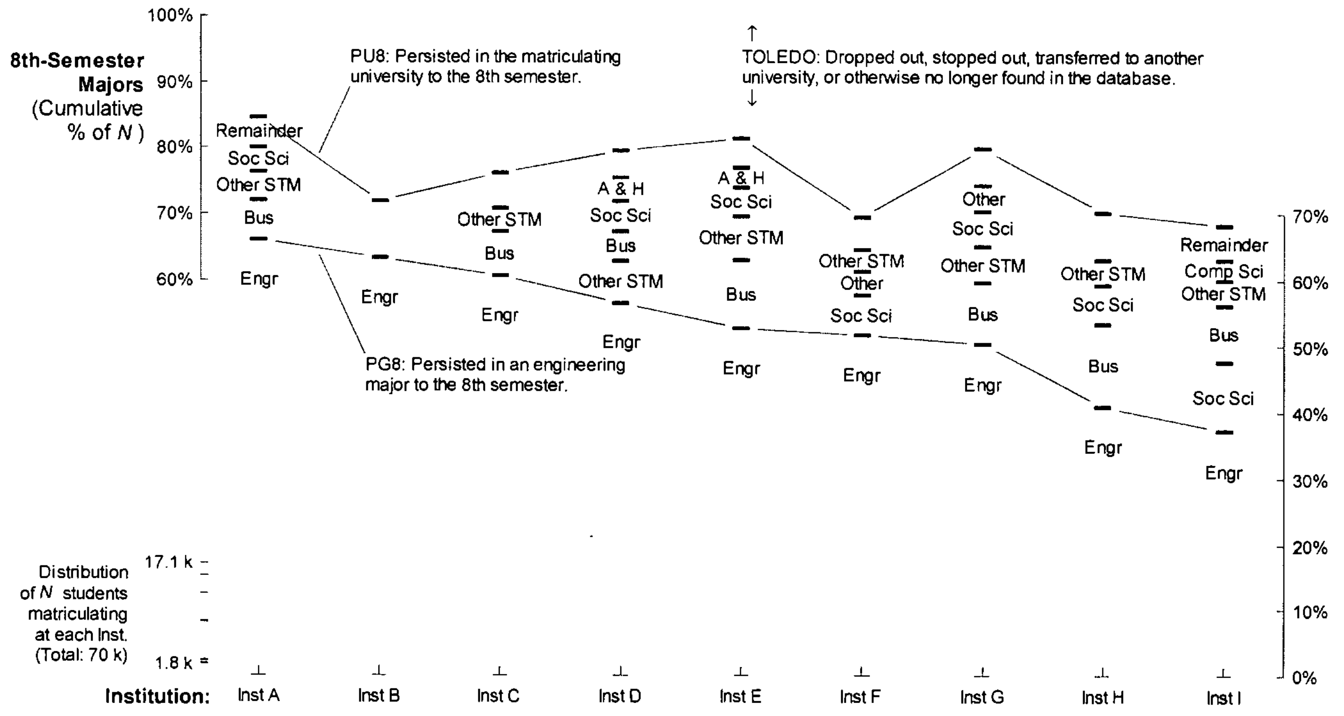
C. Institutional Differences

The NSSE has generated a significant amount of discussion about institutional variability related to differences in engagement. In an interview (Schroeder, 2003), NSSE Director George Kuh summarized those differences. He noted that smaller institutions are generally better at engaging students, but that not all small schools outperform large institutions. Kuh refers to large schools that do well at engagement as being able to "shrink themselves psychologically or intentionally arrange their resources in a variety of ways to engage students across these five benchmarks at relatively high levels." Clearly, the important message is that institutions have control over the level of student engagement; it is not determined simply by the size of an institution.

While institutional decisions affect engagement, we were not able to probe NSSE data at an institutional level. Institutional structure, programs, and/or policies potentially have a strong influence over patterns of persistence as well. With MIDFIELD we can do some exploration of institutional distinctiveness on persistence. Figure 3 is a MIDFIELD persistence chart for institutional comparison, showing the variation in engineering persistence of the nine institutions participating in the MIDFIELD database. For engineering students, PU8 ranges from 68–85 percent at the various institutions, while PG8 ranges from 37–66 percent.

Figure 3 has several noticeable features:

- The institutions are uniformly distributed through the range of PG8, indicating that PG8 is a continuous variable when studied across multiple institutions.
- The trend that students leaving engineering (but remaining enrolled at the same institution) are most likely to go to business appears to be a nearly universal phenomenon. Although other fields are more popular destinations than business at Institutions D, F, and I, business is nearly as popular at Institutions D and I. Certainly, some institutional differences are expected, because of variability of academic offerings and in policies governing access to those offerings.
- As seen in the standard MIDFIELD persistence chart earlier (Figure 1), there is less variability in PU8 than in PG8.
- Whereas a standard MIDFIELD persistence chart (Figure 1) indicates a strong relationship between PU8 and PG8, here we see considerable institutional variation in this relationship. Institutions B and F stand out particularly, in that students at those institutions who leave engineering are more likely to leave the university than students at the other institutions studied.



Students Matriculating in Engineering
Individual MIDFIELD institutions, 'native' (non-transfer) students, 1987-1999.

Figure 3. MIDFIELD persistence chart for institutional comparison, all institutions, 1987–1999.

Institution	PG8 Avg. (SD)	PU8 Avg. (SD)	PG8-Engr	PU8-Engr	Rank of PG8-Engr within Inst.
A	52% (10%)	78% (4%)	66%	85%	1
B	54% (10%)	67% (3%)	63%	72%	1
C	40% (21%)	69% (8%)	61%	76%	1
D	47% (10%)	73% (4%)	57%	80%	2
E	56% (7%)	77% (5%)	53%	81%	6
F	46% (13%)	64% (6%)	52%	70%	4
G	39% (15%)	76% (5%)	50%	80%	3
H	41% (12%)	66% (6%)	41%	70%	5
I	38% (10%)	70% (3%)	37%	68%	5

Table 9. The variation of PG8 at MIDFIELD institutions. Institutions are ordered by their persistence in engineering to the eighth semester.

The total engineering enrollment at each institution in the study period could not be shown because it would uniquely identify each institution. The range of total enrollment, which spans an order of magnitude, is shown at the bottom left of the chart.

Table 9 summarizes the institutional variability of PG8 in the MIDFIELD institutions. The variability in rank can be deceiving. Some institutions have very little variability in the rate of persistence across disciplines, so the rank of engineering persistence can be affected in absence of significant differences in the absolute rate of persistence. The standard deviations shown in the PU8 column reinforce our earlier observation that university persistence has much less variability. Table 9 shows outliers both where persistence is particularly consistent across various disciplines (Institution E has the lowest standard deviation in PG8) and where persistence varies notably by discipline (Institution C, which has nearly twice the typical standard deviation in PG8 and PU8).

D. Grades as an Outcome

Grades are challenging as an educational outcome. While they do not necessarily represent what students have learned, they are accessible and are commonly used to describe undergraduate academic performance (Adelman, 2004). Grades were examined as a possible source of difference between students in engineering majors and those in other majors. In spite of the subjectivity of grades, aggregated results can be illuminating. MIDFIELD data accessed academic records of students whose data were included in the study (Table 10). Grade distributions (as a cumulative frequency of all grades received) are similar, regardless of major. Chi-square analyses confirm no significant differences across majors ($\chi^2 = 3.995$, df $= 30, p = 1$).

While NSSE relied on student self-reported data, and the percentages were slightly different, the overall profiles were similar for NSSE and MIDFIELD. NSSE freshmen and senior engineering students reported having "A" GPAs notably less frequently than students in arts and humanities, but with similar frequency to students in other areas of study. Conversely, engineering students reported having "C" GPAs more frequently than arts and humanities students (see Table 11). However, no significant differences by major emerged in the NSSE data (Table 11) for either freshmen ($\chi^2_{\text{fresh}} = 6.893$, df $= 10, p = 0.736$) or seniors ($\chi^2_{\text{seniors}} = 9.991$, df $= 10, p = 0.441$).

Although the actual percentages vary, the patterns in self-reported grade data mirror MIDFIELD record grade data, and neither shows a statistically meaningful difference in distribution of grades (either as recorded or self-reported) between students across all majors.

Letter Grade	A & H	Bus	Comp Sci	Engr	Other	Other STM	Soc Sci
A	40%*	31%	33%	35%	36%	38%	38%
B	30%	32%	29%	31%	30%	30%	29%
C	16%	21%	19%	19%	19%	17%	17%
D	4%	6%	6%	6%	5%	5%	5%
F	6%	6%	7%	5%	6%	6%	6%
W	4%	4%	5%	4%	4%	4%	4%

* Proportion of students receiving this grade to all students in the major.

Table 10. Cumulative frequency of transcript-recorded grades in MIDFIELD data.

E. The Relationship between Engagement and Persistence

Our other findings show the similarity of engineering and other fields of study with respect to persistence (from MIDFIELD) and outcomes and engagement (from NSSE). What remains to be explored is whether there is a relationship between engagement and persistence (including the temporal aspect of that relationship), and if that relationship is similarly consistent for students across the engineering and non-engineering majors. It is not possible to explore this relationship with the MIDFIELD or NSSE databases. Because the MIDFIELD database consists of academic transcript data, it is useful for studying outcome measures of persistence and grades, but not the engagement factors studied in this work. While the NSSE database measures both engagement and self-reported outcomes, this study uses cross-sectional data rather than longitudinal data, so responses cannot be paired by subject. The PIE survey data from the APS Longitudinal Cohort make it possible to study the connection between engagement and persistence. Based on the findings of Seymour and Hewitt (1997), who found that a lack or loss of interest in science, mathematics and engineering, as well as a belief that non-engineering majors offer a "better education" were both factors that made students less likely to persist, we hypothesized that disengagement from engineering courses, accompanied by engagement in liberal arts courses, might be a precursor to leaving engineering.

Figure 4 displays self-reported academic disengagement over time for the persisters only. The black line shows disengagement from engineering-related courses and the gray line shows disengagement from liberal arts courses. The normalized variable scores are plotted along the y-axis, where 1.00 means the combined frequency of events signaling disengagement is "always" and 0.00 means the combined frequency is "never." The general trend is that academic disengagement from *both* engineering and liberal arts courses increases with time for persisters. (Linear regression analysis was performed on both data sets, and t-tests showed that the slopes of the regression lines are significantly higher than zero for both cases with $p < 0.05$.)

This observation is significant when it is considered in light of the persistence data displayed in Figure 1. In other words, although students persist in engineering at a higher rate than do students of other major groups plotted in Figure 1, the PIE data suggest that

	Letter Grade	A & H	Bus	Comp Sci	Engr	Other	Other STM	Soc Sci
	A	45.9%*	32.4%	37.8%	37.0%	--	41.5%	36.9%
Freshmen	B	46.0%	53.8%	46.0%	48.4%	--	47.6%	51.6%
	C	8.2%	13.8%	16.2%	14.6%	--	10.8%	11.4%
	A	51.7%*	35.2%	42.0%	37.0%	--	45.6%	43.7%
Seniors	B	44.1%	56.4%	49.3%	52.4%	--	48.1%	49.9%
	C	4.2%	8.4%	8.7%	10.5%	--	6.3%	6.4%

* Proportion of students receiving this grade to all students in the major.

Table 11. Distribution of self-reported cumulative grade-point average in NSSE data.

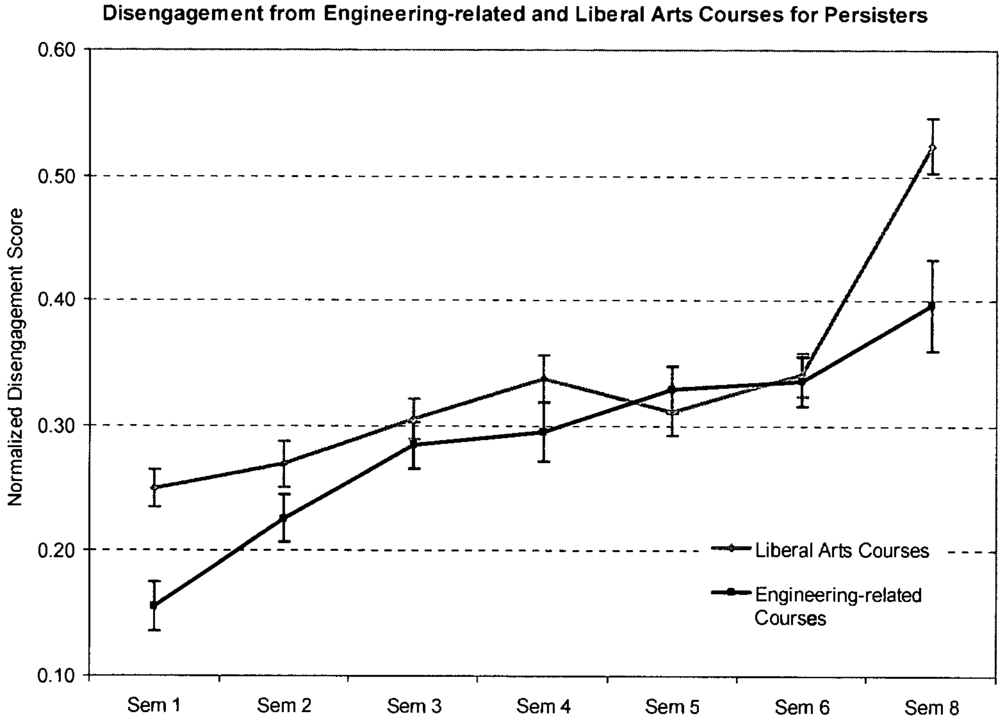


Figure 4. Academic disengagement from engineering-related and liberal arts courses for persisters. Error bars display standard errors of means. No survey was administered in Sem 7.

their academic disengagement increases over the course of their undergraduate education. It would have been intuitive to expect high persistence to be associated with steady or increasing engagement but the data suggest otherwise. If we find ways to increase the engagement of students over time, it may be that much higher persistence rates are possible in all majors (Fortenberry et al., 2007).

Figure 5 displays self-reported academic disengagement over time from engineering-related courses only for persisters and non-persisters. Similar to the persisters shown in Figure 4, the non-persisters show a disengagement from engineering-related courses that increases steadily over time. The rate of disengagement for non-persisters, however, appears to be higher than that for persisters since the slopes of the non-persister lines are consistent and steeper than the slope of the persister line. This difference was shown to be statistically significant for the Sem4 NP line and the P line, although not for the Sem2 and Sem3 NP lines, which is likely due to their much smaller sample sizes.

Taken as a whole, the analysis of data from the Persistence in Engineering survey not only demonstrates that a relationship between academic engagement and persistence exists, but also that the relationship is nuanced, and that there are aspects of it that are not captured in the MIDFIELD and NSSE data.

V. CONCLUDING DISCUSSION AND NEXT STEPS IN RESEARCH

We have compared persistence and engagement of students in undergraduate engineering and other college majors. We found that, in general, engineering students are more persistent than and as engaged as other college students. In looking at outcome and engagement factors ranging from grades and gains in general education to course-related interactions with faculty and time-on-task, students who matriculate in engineering do not stand out relative to students in other majors. To the extent that educators and policy-makers have concerns about the dearth of engineers being prepared in this country (Duderstadt, 2007; Fortenberry et al., 2007), our data provide compelling evidence that lack of retention is not the major cause of the deficiency.

Our findings align with and extend those of Seymour and Hewitt (1997), who found that students who chose to discontinue an SME major were not "different kinds of people" from those who succeeded in an SME major. In this study, we were able to confirm the similarities between those who matriculate in engineering and students in other fields.

Based on prior research and engineering degree programs' high course load and workload requirements, we expected to find that engineering students would report higher stress and greater dissatisfaction with their programs compared to other students. We also expected to find low rates of persistence, especially among women and students of color. Because of the "hands-on" nature of engineering, we expected engineering students to report more integrative learning and a greater level of practical competence than those in other majors (while engineering students did report higher levels of practical competence, the effect size of these differences was negligible). While one might also expect that heavy course loads would lead to students being less satisfied with their overall college experience or to be less involved in co-curricular endeavors such as athletics, campus organizations, and volunteer work, this is not the case. Engineering students are as engaged and satisfied with their overall college experience and growth as are their peers in other majors.

In short, we expected to find lower rates of persistence, higher rates of attrition, and lower rates of satisfaction among engineers

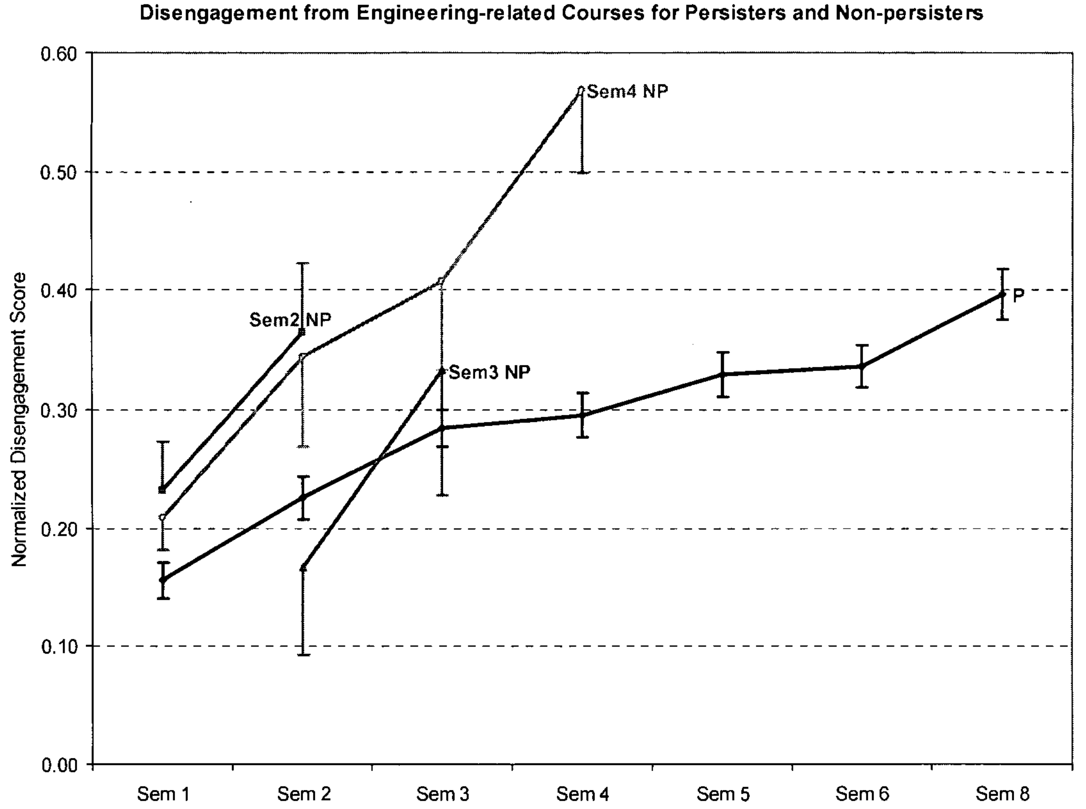


Figure 5. Academic disengagement from engineering-related courses for persisters (P) and non-persisters (NP). Non-persisters are identified by the last semester they completed in engineering. Error bars display standard errors of means, and are shown as single-sided in some cases to avoid overlapping other data. No survey was administered in Sem 7.

compared to other majors. These expectations were simply not borne out by the data. Engineering evidences the highest rate of persistence of any group of majors we studied. Of course, some students who enroll in engineering programs as first-year students do leave—about 40 percent. Yet, our data suggest that a certain amount of shifting around is expected of students in all majors. Qualitative data from other sources show that many engineering students make thoughtful decisions about their major and do not regret their decisions either to stay or leave the major (Lichtenstein et al., 2007). Those familiar with college students know that most undergraduates choose, un-choose and re-choose their college majors. Engineering majors are no different, except for the fact that, after matriculation, engineering attracts far fewer students than any other major.

Frankly, the observed differences between engineering and other majors are less striking than the similarities. There are, however, two distinguishing and significant characteristics of those who persist in engineering: (i) over 90 percent of eighth-semester students who are studying engineering had identified engineering as their major when they matriculated to college (this is much higher than any other major), and (ii) the engineering population is disproportionately male.

It would be a misinterpretation of our findings to conclude that everything is fine in engineering education. Our findings do point to opportunities for improvement. That 90 percent of those studying engineering in their eighth semester in college were on the engineering pathway when they matriculated suggests that engineering has a problem attracting students. This may be because those who matriculate undecided whether to major in a non-engineering field (including STM majors) are not attracted to engineering or because students believe that engineering requires a commitment prior to matriculating to college, beginning with high school preparation, college selection, etc. These possibilities make engineering seem like a "closed club" that is unattractive and/or opaque to those not in the club, and that "unlocking the clubhouse," to borrow the metaphor used by Margolis and Fisher (2002), is one of the keys to graduating more engineers.

Interpreting our findings as suggesting that any less time, money, and effort should be put into student support programs, *would be a significant misinterpretation.* The focus that the engineering education community has given to retaining engineering students is likely responsible, at least in part, for the present level of persistence in engineering. Furthermore, the strategies that have typically favored improvements in persistence have also shown the greatest improvements for women and students of color (Hoit and Ohland, 1998; Knight, Carlson, and Sullivan, 2007). To abandon our concern for persistence would disproportionately harm those populations.

Maintaining engineering's focus on persistence is also important, given that even with our current level of persistence we are graduating fewer engineers now than 20 years ago, both in terms of absolute numbers and as a percentage of all college degrees.

Our growing understanding of how particular in-class and out-of-class strategies work to increase persistence in engineering may be useful in making engineering more attractive and transparent to non-engineering majors (a need we identified above). In other words, how might approaches that help retain students in engineering also be used to attract students to engineering? Lessons learned from creating hands-on freshmen experiences (Hoit and Ohland, 1998), introductory design courses (Knight, Carlson, and Sullivan, 2007), and service learning (Coyle, Jamieson, and Oakes, 2006) are relevant to creating transparency and attractiveness. These lessons include:

1) Shifting to a "Passion Paradigm" in Designing Programs—distilling theory and practice to their essence and then trusting student passion to customize engineering learning. In this issue, Chubin et al. (2008) offer many suggestions about how the culture of engineering education might change to welcome more students. Based on the work of Stevens et al. (2008), it is particularly important that prospective migrators have the opportunity to identify with engineering.

2) Re-Considering the Curriculum to Minimize What is Considered Essential and Required (Duderstadt, 2007). Carnegie-Mellon has thought along these lines, offering a variety of engineering courses for students their first year that provide substantive exposure to the nature of engineering work within the various fields of engineering. These courses allow students to "shop," and are preparation for choosing (or not choosing) an engineering major. Other institutions have also found innovative ways to address this issue and see migration rates into engineering as high as 25 percent (Donaldson and Sheppard, 2007). Some are as radical as offering a B.A. degree in engineering (Arizona Board of Regents, 2007), while others promote student-designed engineering majors.

3) Viewing Engineering Education as Part of a Larger System: Institutional policies can also drastically affect whom we graduate. MIT adjusted its admissions policies to help bring about gender balance (Widnall, 2000), and Carnegie Mellon affected the make-up of its computer science study body by changing admissions criteria and first-year courses (Margolis and Fisher, 2002). Higher education policies and practices must also articulate with pre-college programs to keep all pathways open. An example of a positive trend along this line is the dedication in 2007–2008 of ASEE regional activities to working with pre-college teachers, as announced by President Melsa (2007) in his June 2007 speech.

If we want to attract more students and a broader range of students, we have to do things differently. Within the MIDFIELD data, which include some of the largest engineering programs in the country, enrollment in engineering has varied little since the late 1980's. Both ordinary and extraordinary measures are needed.

We note that there is a need for further research into how students make decisions about their major, what their post-graduation endeavors (e.g., work, graduate school) will be, what factors affect these decisions, and how engagement and outcome are related. There are still many unanswered questions, such as:

1) What does the pathway to a major look like for those students whose college career involves studying at two or more institutions? (Some of the "TOLEDO" students in Figure 1 would fall into this category.) Does this multi-institutional pathway differ from the pathways of those studying engineering at a single institution?
2) How are engagement factors related to particular engineering-related outcomes (e.g., ABET outcomes)?
3) How do students' perceptions of their own grades and those of others affect their college experiences? What is the source of the potential discrepancy between actual grades and self-reported grades suggested by Tables 10 and 11?
4) How is the pathway to a major affected by admissions policies to the university and to the major? To what extent is engineering pre-determining persistence by these policies?
5) What does academic engagement (and disengagement) look like over time for students in majors other than engineering?

It will be important to understand and develop answers to these types of questions at the national level, as well as at the institutional and departmental levels.

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