Outcomes of a Longitudinal Administration of the Persistence in Engineering Survey

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BACKGROUND
Understanding more about student decisions to leave engineering may lead to higher retention. This study builds on the literature and focuses on the experiences of a cohort of students who aimed to complete their undergraduate work in 2007.

PURPOSE (HYPOTHESIS)
This paper presents the outcomes of the longitudinal administration of the Persistence in Engineering survey. The goal was to identify correlates of persistence in undergraduate engineering education and professional engineering practice.

DESIGN/METHOD
The survey was administered seven times over four years to a cohort of students who had expressed interest in studying engineering. At the end of the study, the participants were categorized as persisters or non-persisters. Repeated measures analysis of variance was used, in conjunction with other approaches, to test for differences between the groups.

RESULTS
Persisters and non-persisters did not differ significantly according to the majority of the constructs. Nevertheless, parental and high school mentor influences as a motivation to study engineering, as well as confidence in math and science skills, were identified as correlates of persistence. Intention to complete an engineering major was also a correlate of persistence; it appears to decline sharply at least two semesters prior to students leaving engineering. The findings also suggest that there might be differences among non-persisters when they are further grouped by when they leave engineering.

CONCLUSIONS
Facilitating higher levels of mentor involvement before college might increase student motivation to study engineering, and also constitute a mechanism for fostering confidence in math and science skills. Since the intention to complete an engineering degree decreases well before students act, there may be opportunities for institutions to develop targeted interventions for students, and help them make informed decisions.

KEYWORDS
longitudinal study, persistence, retention.

I. INTRODUCTION

The Academic Pathways Study (APS) of the Center for the Advancement of Engineering Education (CAEE) built upon and extended knowledge related to retention in engineering education by employing quantitative and qualitative approaches to establish a longitudinal research base on engineering student learning (Sheppard, 2004). This paper reports the outcomes of a longitudinal administration of the Persistence in Engineering (PIE) survey instrument, which was developed as a part of the APS (Eris, 2005).

The PIE Survey intends to identify correlates of persistence in engineering. It explores two levels of persistence: academic and professional. "Academic Persistence" is operationalized as completing a major in engineering, and "Professional Persistence" is operationalized as conducting research in, teaching, and/or practicing engineering for at least three years after graduating with a bachelor's degree in engineering.

The PIE survey was used primarily as an exploratory tool within the APS. The insights gained during the seven administrations of the PIE survey were used to adapt the final version of the instrument to a compact survey, termed "APPLES" (Academic Pathways of People Learning Engineering Survey) that utilizes a select group of key PIE constructs (Sheppard, 2010). In the final phases of the APS, APPLES was administered to a stratified sample of students at 21 colleges and schools in the United States in a cross-sectional manner.

II. BACKGROUND

Much of the work that has been undertaken in order to advance engineering education has focused on broad curricular issues or specific disciplinary reforms. However, a few studies have used longitudinal methods to better understand the engineering student experience from a developmental perspective. Because a primary focus of the current research is on persistence in engineering (both academic and professional persistence), we highlight three of these prior longitudinal studies that have also had a persistence focus.

Huang, Taddese, and Walter (2000) examined how gender and ethnicity relate to entrance, persistence, and attainment of postsecondary science and engineering education. The data collected during two previous survey-based longitudinal studies, the National Educational Longitudinal Study of 1998 (NELS:88) and the Beginning Postsecondary Longitudinal Study (BPS) were analyzed. Starting in academic year 1988–89, NELS was conducted with eighth-graders through high school and into college or the workforce, and BPS, with college students starting their first college year (1989–90) to five years later (1993–94). The following factors were found to be significant for choosing to major in science and engineering, regardless of ethnicity or gender: enrollment in advanced science courses in high school, self-motivation to study science, parents with advanced degrees, and parents with high expectations for their child's education. Upon a student's decision to major in engineering, ethnicity and gender were found to be factors in degree completion.

Besterfield-Sacre et al. (1995, 1997, 2001) developed the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS) in order to understand how "students' initial attitudes about engineering and their abilities" may relate to attrition in engineering. Data collected at a single institution showed that student attitudes may change significantly during their first college year. Positive shifts in the attitudes towards "working in groups" and the perception of engineering as a "precise" science were likely. Using the PFEAS and demographic data, students who left engineering at the end of their first-year of study were differentiated into two categories: students who left engineering in good academic standing as compared to those who left in poor academic standing. The analysis revealed that students who left engineering in good academic standing reported lower attitudes on a variety of measures related to their impressions of engineering and confidence in engineering and science skills. In contrast, students who left in poor academic standing had more positive attitudes towards engineering and their abilities compared to students who either stayed in engineering or those who left in good academic standing.

In the *Women and Men of the Engineering Path* study, Adelman used the data from the 11-year college transcript history from the High School and Beyond/Sophomore Cohort Longitudinal Study (1982–93) and responses to the Cooperative Institutional Research Program Survey in order to track the academic progress of engineering students in college (Adelman, 1998). The women who left engineering were found to have earned higher grades than the men who left, although women and men earned similar grades in engineering courses. Furthermore, women who left engineering did not leave because of poor academic performance although they cited a higher degree of "academic dissatisfaction" as a reason for leaving. The "perception of overload" was found to be a decision factor in leaving engineering for both women and men.

These three studies illustrate that there is no simple or singular reason for why students leave an engineering major. The reasons for those with higher GPAs may be different from those with lower GPAs, the reasons may be affected by gender or ethnicity, and college factors (such as workload) may come into play.

The complex nature of persistence in engineering is also underscored by the seminal work on persistence in science and engineering education, by Seymour and Hewitt. They interviewed over 300 juniors and seniors at seven institutions about their decisions to "switch out of" or stay in science, math and engineering majors (Seymour and Hewitt, 1994, 1997). The researchers found that there was "no single overwhelming concern for the decision to switch, rather students engaged in a process of reactions to problems with the science and engineering major, concern about career, and the merits of alternative majors." The decision to switch was rooted in the students' "concern about the future," as well as "structural or cultural" sources within the institution, and not solely the academic rigors of the science and engineering majors. Furthermore, students who stayed and those who switched out raised the same set of concerns about majoring in science and engineering.

These prior studies on persistence in engineering have inspired and informed the PIE longitudinal survey work that is reported in this paper. An additional source of inspiration are the findings of Brainard, who administered a survey to a cross-sectional population of more than 8,000 freshman to senior engineering students at 29 different institutions in order to assess engineering student perceptions of the educational climate (Brainard, 1999). Male students consistently reported higher self-confidence in academic measures, as well as confidence that engineering was the "right major," while female students reported being more "overwhelmed by the fast pace and heavy workload" of majoring in engineering. Most academic confidence measures were the lowest during freshman year and peaked during senior year, but some measures did not follow this trend. This finding suggests the need for a longitudinal analysis of engineering students' perceptions and skills to capture the changes.

More recently, Li, Swaminathan, and Tang (2009) reviewed the literature on the characteristics of engineering students that affect college enrollment and retention with the intention of developing a classification system. The outcome of their analysis is a classification scheme that is made up of three main categories: external, internal, and demographic student characteristics. Internal student characteristics are further grouped into cognitive and affective characteristics, whereas external student characteristics are grouped into community, college, and society influence. In the next section, we will relate some of the published work they analyzed to the PIE constructs. It is also relevant to highlight one of their key conclusions, which is that many of the reviewed publications failed to model interaction effects between the student characteristics that were identified.

III. Instrument Development

The PIE survey was developed by an interdisciplinary team. Its development process and conceptual framework has been documented in detail (Eris, 2005). A brief summary of the key developmental issues will be addressed here.

The PIE constructs, which were hypothesized to be correlates of persistence in engineering, can be grouped as follows:

1. Constructs that have been operationalized in existing surveys. Some of these constructs were already operationalized in an engineering education or persistence in engineering context, and others were not.
2. Constructs that are known from the literature to be related to persistence in engineering, but have not been operationalized in a survey. These constructs were identified mainly through qualitative methods such as ethnographic studies or interviews.
3. Constructs that are not based on the literature. Some of these constructs emerged from preliminary discussions that were held within the APS research community prior to data collection.

By integrating constructs from these three groups in a single instrument, the PIE survey leverages existing instruments relevant to persistence in engineering, operationalizes persistence factors that have been explored in studies that were not based on a survey approach, and conceptualizes new persistence factors. The resulting PIE constructs are defined in Table 1. Rationale on how each construct is related to persistence in engineering is also provided.

PIE Construct	Construct Definition and Rationale
1. Persistence in Engineering (a. Academic b. Professional)	This construct is defined as two dimensions: "academic persistence" is graduating with an undergraduate engineering degree, whereas "professional persistence" is an intention to *practice* engineering for at least three years after graduation. Although the second is generally contingent on the first, not all students who graduate with an engineering degree practice engineering.
2a. Motivation to Study Engineering: Financial	Motivation to study engineering due to the belief that engineering will provide a financially rewarding career. In Astin's study (Astin, 2004), engineering majors frequently reported that the "chief benefit of college is making money." Seymour found that the belief "science, mathematics and engineering career options and rewards are not worth the effort to get the degree" influenced the decision to leave engineering (Adelman, 1998; Seymour and Hewitt, 1997). This construct was borrowed from the PFEAS.
2b. Motivation to Study Engineering: Parental Influence	Motivation to study engineering due to parental influences. Astin found that having a father who is an engineer was an indicator for engineering as a career choice (Adelman, 1998). However, Seymour's findings suggest that men leaving science and engineering majors are those most likely to have followed a "family career tradition" into science and engineering fields (Seymour and Hewitt, 1994, 1997). This construct was borrowed from the PFEAS.
2c. Motivation to Study Engineering: Doing Social Good	Motivation to study engineering due to the belief that engineers improve the welfare of society. Since Astin reported that engineering majors frequently voiced the belief that "individuals can't change society" (Astin, 1993), it is relevant to investigate whether this motivation construct is a persistence factor. Also, Nicholls reported that non-STEM students were more likely to be motivated by influencing social values than STEM students (Nicholls et al., 2007). Thus, students who leave engineering might respond more strongly to this construct than the ones who stay. This construct was borrowed from the PFEAS.
2d. Motivation to Study Engineering: High School Mentor Influence	Motivation to study engineering due to influence of high-school teacher(s) and/or advisor(s). The Seymour study yielded qualitative findings indicating this motivation construct might be a persistence factor (Seymour and Hewitt, 1997).
2e. Motivation to Study Engineering: College Mentor Influence	Motivation to study engineering due to the influence of mentor(s) while in college. This construct extends the rationale of construct 2d into the college years. Also, there is evidence suggesting that students who drop out of engineering do not seek counseling services that are offered by the institutions (Schuman,1999).
3a. Confidence in Math and Science Skills	Math and science skills refer to proficiency in science, critical thinking, real-world problem solving, and computation. Engineering majors frequently reported "growth in analytic and problem-solving skills" during their undergraduate careers in Astin's study (1993). Besterfield-Sacre also identified "low confidence in basic mathematics, science, and engineering skills" as a characteristic of engineering students who did not persist (Besterfield-Sacre et al., 1995, 1997). Burtner identifies confidence in math and science ability as a predictor for short and long term persistence in engineering (Burtner, 1994).
3b. Confidence in Professional and Interpersonal Skills	Professional and interpersonal skills refer to proficiency in business, communication and teamwork. The construct explores the relationship between self-efficacy and persistence in engineering education. Seymour identified "feeling discouraged/losing confidence due to low grades in early years" as a persistence factor (Seymour and Hewitt, 1997). Seymour's findings are relevant to all three constructs that are associated with self-reported confidence.
3c. Confidence in Solving Open-Ended Problems	Level of confidence in the ability to engage problems with multiple solutions. Although there is agreement that practicing engineers solve open-ended problems, it is not clear whether engineering curricula successfully prepare students to tackle such problems (Dym, 2005).
4a. Perceived Importance of Math and Science Skills	Perceived importance of math and science skills, as measured by Construct 3a, in becoming a successful engineer.
4b. Perceived Importance of Professional and Interpersonal Skills	Perceived importance of professional and interpersonal engineering knowledge and skills, as measured by Construct 3b, in becoming a successful engineer.
5. Knowledge of the Engineering Profession	Level of familiarity with the engineering profession. Familiarity is measured by the extent of interaction with professional engineers and/or exposure to professional engineering environments.
6. Exposure to Project-Based Learning (a. Individual Projects, b. Team Projects)	Level of exposure to project-based learning (PBL) pedagogies in courses. The majority of engineering students enjoy courses which utilize project-based learning methods (Dym, 2005). Recent ABET requirements have resulted in an increase in design courses in engineering curricula, which are often taught using PBL.

Table 1. Definitions and rationale of the PIE survey constructs.

PIE Construct	Construct Definition and Rationale
7. Frequency of Involvement in Extracurricular Activities	In Astin's study, engineering majors reported low satisfaction with student life, including participation in extracurricular activities (Astin, 1993).
8. Perceived Importance of Involvement in Extracurricular Activities	Tracking the perceived importance of extracurricular activities in parallel with the frequency of involvement in extracurricular activities allows us to place the level of involvement in its proper context.
9. Curriculum Overload	Level of difficulty in coping with the pace and load demands of engineering-related courses. Seymour identified the level and the large volume of work required in the engineering curriculum, coupled with the rapid pace at which the information must be absorbed, to be a strong persistence factor (Seymour and Hewitt, 1994, 1997). Adelman reported that although the engineering major credit loads are not significantly higher than those of other majors, engineering students "perceive overload because of the high ratio of classroom, laboratory, and study hours to credit awarded" (Adelman, 1998).
10. Financial Difficulties	Level of comfort with financing college expenses. Seymour found having financial difficulties to be a persistence factor (Seymour and Hewitt, 1994, 1997).
11. Academic Disengagement (a. Non-Engineering Related, b. Engineering Related, c. Overall)	Frequency of events signaling disengagement from engineering and non-engineering courses. Seymour found that a lack of or loss of interest in science, mathematics and engineering, as well as a belief that non-engineering majors offer a "better education," were both persistence factors (Seymour and Hewitt, 1994, 1997). Thus, disengagement from engineering courses, while remaining engaged in non-engineering courses, might be a precursor to leaving engineering. On the other hand, disengagement from both engineering and non-engineering courses might be a precursor to leaving college. This construct was borrowed from the Your First College Year (YFYC) survey (John N. Gardner Institute for Excellence in Undergraduate Education, 2010)
12. Frequency of Interaction with Instructors	Frequency of interactions with faculty and teaching assistants. Seymour found "poor teaching by science, mathematics, and engineering faculty" to be a strong persistence factor (Seymour and Hewitt, 1994, 1997). Strong correlation between student-faculty interaction and college GPA and retention have been reported (French, 2003). Also, engineering faculty often rely heavily on TAs in order to carry out teaching responsibilities, who might lack adequate teaching experience, which may also be a persistence factor. Furthermore, a significant percentage of TAs in engineering are foreign students, and experience difficulties in classroom management and communication (Seymour and Hewitt, 1997). This construct was borrowed from the PFEAS.
13a. Satisfaction with Instructors	Level of satisfaction with interactions with faculty and teaching assistants.
13b. Satisfaction with Academic Facilities	Level of satisfaction with academic facilities, such as classroom and laboratories. Seymour identified inadequate advising; concerns with teaching, labs, or recitation support; and poor facilities as persistence factors (Seymour and Hewitt, 1994, 1997). This construct was borrowed from the PFEAS.
13c. Overall Satisfaction with Collegiate Experience	General satisfaction with the overall quality of the college experience. This question is asked at the end of the survey to obtain a "Gestalt-like" judgment. Continued dissatisfaction with the overall college experience is hypothesized to result in low persistence.
Demographic Variables	Sex, Ethnicity, Socio-economic Status, Citizenship Status.

Table 1. Continued...

IV. Data Collection Methodology and Internal Consistency of Survey Constructs

A. Survey Administrations and Participants

The PIE Survey was administered longitudinally to a cohort of 160 students, 40 at each of the four CAEE campuses, beginning their first year in college. In total, there were seven administrations-two during the first year (January 2004, April 2004), two in the sophomore year (November 2004, April 2005), two in the junior year (November-December 2005, April-May 2006), and one in the senior year (April-May 2007). The four CAEE campuses are briefly described in Table 2. The 40 students at each campus make-up from 6 percent to 41 percent of the matriculating engineering cohort at the schools.

All matriculating students in the Fall of 2003 at the four campuses who indicated an interest in studying engineering were invited to participate in the study. Particular attention was paid to recruiting women and underrepresented minorities in order to achieve over-sampling of these groups. Interested students then self-selected to be a part of the study.

Based on responses to demographic questions asked in the winter 2004 survey, the students in the cohort were not married (100 percent). The majority were U.S. citizens (83 percent) and they had a modal age of 19. The cohort is 61 percent male and 39 percent female, and they self-identify by ethnicity as the following: 42 percent White/Caucasian, 23 percent Black/African-American, 18 percent Asian/Asian-American/Native Hawaiian/Pacific Islander, 3 percent Mexican American/Chicano/Latino, and 14 percent Other/Multiracial. A detailed description of the demographics of

School Pseudonym	2004 Carnegie Classification & Brief Description	PIE Cohort as percent of Engr. Cohort	Women in PIE Cohort	Women in Engr. Cohort
Technical Public Institution (TPub)	Specialized Institution-Engineering; ¾ of its 3,350 students enrolled in undergraduate programs with approximately 600 entering freshmen in engineering.	6.7%	50.0%	23.6%
Urban Private University (UPri)	Doctoral Research-Extensive; comprehensive, historically Black private comprehensive university, 10,000 students, 180 entering the engineering program each year.	41.3%	33.3%	29.5%
Suburban Private University (SPri)	Doctoral Research-Extensive; enrollment of about 14,000 students, divided equally between graduate and undergraduate students	13.1%	30.8%	28.2%
Large Public University (LPub)	Doctoral Research-Extensive; a very large public research university with 40,000 students.	6.3%	42.1%	19.5%

Table 2. PIE school characteristics.

the survey participants was published in a CAEE technical report (Sheppard et al., 2009). Note that oversampling of women participants was achieved since the 39 percent female make-up is higher than any of four schools individually (see Table 2).

B. Construct and Item Development

During the seven administrations, the PIE constructs were continuously refined. The items that make up the constructs are fairly stable since any significant changes in the actual survey questions would limit our ability to conduct a longitudinal analysis. However, the groupings of items under some of the constructs, as well as the definition of those constructs, changed slightly based on the outcomes of qualitative and statistical analysis of the responses in order to increase the internal consistency. In a small number of cases, it was necessary to modify the actual survey items as well. Those cases were clearly documented, and the constructs such items were associated with were tracked back and are reported only for the administration during which a significant item change had occurred; construct values of those constructs for previous administrations are not reported or included in the analysis. This consideration applies to Constructs 4b and 13c.

The continuous development of the survey also meant that new topics of inquiry were identified over time. Additional constructs were developed to address the new topics after the second administration, and were measured beginning with the third administration. This consideration applies to Constructs 1b, 2e, 7, 8, 9, and 10.

The final set of PIE constructs and associated items can be found in the Appendix. Cronbach alpha internal consistency values for multi-item constructs and item-total correlations for those items are also reported based on the fifth administration of the survey (Fall 2005). The internal consistency reliability value for Construct 2d is not reported since those items were only administered during the second administration of the survey (Spring 2004). Since reliability coefficients are estimates of the proportion of true-score variance captured by the observed score variance, minimum alphas of 0.6 to 0.7 are generally acceptable (Crocker and Algina, 1986).

The items making up the survey constructs are presented in the Appendix. The score for each construct was normalized by a linear mapping to a scale of 0 and 1 since different survey items had different response scales.

V. Analysis Methodology

A. Persister and Non-persister Groupings

At the end of the four years and the seven administrations of PIE, the subjects were characterized into groups according to their persistence status: persisters, who either graduated or were still working toward graduation with an engineering degree by the end of the study; and non-persisters, who decided not to pursue an engineering degree at some point during the study.

The group membership characterization was based on transcript data that were available for each academic semester or quarter a subject had been a part of the study. Subjects who had either graduated with an engineering degree, or were still majoring in engineering (had an engineering major declared on their transcript) as of the summer of 2007 were termed persisters (Ps). Non-persistence was defined as a non-engineering major appearing on a subject's transcript. The semester in which the subject declared a non-engineering major became that subject's non-persistence category label. For instance, a subject who declared a non-engineering major in semester 3 was placed in the non-persister 3 category (NP3). A few subjects left the institutions they were enrolled in and could not be tracked, and therefore, were not included in the analysis. Table 3 illustrates the temporal relationships between the academic semesters, the survey administrations, and the persister groups.

Attrition was relatively low in the study; we were able to characterize 141 of the initial 160 subjects according to the guideline outlined above. The specific membership counts for the valid categories in the study were: 107 Ps, 1 NP1, 11 NP2s, 7 NP3s, 14 NP4s, and 1 NP6.

Semester	Early Spring 04	Late Spring 04	Fall 04	Spring 05	Fall 05	Spring 06	Spring 07
Survey	Admin. 1	Admin. 2	Admin. 3	Admin. 4	Admin. 5	Admin. 6	Admin. 7
Persister/	P	P	P	P	P	P	P
Non-	NP4	NP4	NP4	NP4			
Persister	NP3	NP3	NP3				
Group	NP2	NP2					

Table 3. The temporal relationships between the academic semesters, the survey administrations, and the persister groups.

Major	Percent of PIE Cohort	Percent of Engineering Cohort
Computer Eng. & Science	17	16
Engineering	6	19
Electrical Eng.	12	16
Mechanical Eng.	17	10
Chemical Eng.	16	9
Civil Eng.	10	7
Industrial Eng. & Management	6	5
Geological Eng.	6	8
Aeronautical & Astronomical Eng.	4	3
Materials Science & Eng.	4	5
Other Eng.	2	2

Table 4. Distribution of the major of students in the Engineering and PIE Cohorts at the four study institutions.

In terms of gender make-up, the 107 Ps consist of 43 percent women, and the 34 NPs of 29 percent. Additionally, the 107 students in the persister category cover the range of engineering majors offered at the four study institutions, and their distribution across these majors are generally representative of the majors of the engineering students at the institutions as a whole (see Table 4).

Therefore, of the 141 study participants considered, 75 percent of them persisted in an engineering major. This level of persistence is comparable to that reported by Lichtenstein et al. (2010) who used a longitudinal dataset of over 11,000 college students to explore persistence in a number of disciplinary fields. It is higher than the recently published persistence number of 57 percent by Ohland et al. (2008) based on over 300,000 students at nine institutions; the difference is most likely mainly due to Ohland et al. including in their count students who matriculated college but were no longer enrolled at the same institution at the eighth semester point.

B. Statistical Analysis

The first step was to sanitize the data, including checking for data entry errors and missing data. Descriptive analysis procedures (e.g., variance ranges, item and construct-level skewness, scatterplots) revealed that the constructs used in the inferential analyses did not violate univariate or bivariate normality or variance homogeneity assumptions. Missing data were intensively examined and no more than one or two students missed completing the entire questionnaire for each administration. In addition, for some administrations a few students did not respond to individual items pertaining to one or more constructs. Further analysis revealed there was no interaction between persister status, sex, ethnicity and the missing responses and no missing value imputation procedures were subsequently employed. Missing data in the repeated-measures analyses of variance (ANOVA) were handled with list-wise deletion.

The primary challenge with the data analysis was that the number of groups changed with time (by definition, the different non-persister groups exited the study at different times). This meant that the data were not amenable to a simple repeated-measures ANOVA. Repeated-measures analyses were iteratively performed for each construct with all of the data up to each time point. For example, at semester 4, all of the construct data from the persisters and those non-persisters who left after semester 3 (persisters, NP3s and NP4s) were analyzed, but not the data from those who left prior to that semester (NP2s). This meant that 4 distinct repeated measures analyses were performed per construct (from and to administrations $1 \mapsto 2$, $1 \mapsto 3$, $1 \mapsto 4$, and $1 \mapsto 7$). Although the single NP6 participant was included in the first three repeated measures analysis as a non-persister, it did not make sense to report the outcomes of an administration $1 \mapsto 6$ analysis. Wilks' lambda (Marcoulides and Hershberger, 1997) was used as the omnibus test statistic and *post hoc* polynomial tests of trends (Shavelson, 1996) were performed.

Independent means t-tests or one-way ANOVAs, as appropriate, were used to identify differences between persister groups at each time point (Bonferroni adjustments were conducted for *post hoc* tests). Similarly, one-way ANOVAs were used within each of the persister groups to identify differences between consecutive time points. ANOVA homogeneity of variance assumptions were checked with Levene's test (Shavelson, 1996) and occasional differences in cell variances were found due to restricted score ranges that occurred when the sample size for a non-persister group was considerably smaller than the persister group. This situation prompted the use of graphs and an examination of the item responses and construct scores to support the statistical results. Likewise, the primary assumption underlying repeated-measures designs is the variance-covariance assumption of circularity (Marcoulides and Hershberger, 1997). This assumption was tested with Mauchley's test of sphericity (Kirk, 1995) and it was tenable for all constructs. Except as noted, $\alpha = 0.05$ and all tests were non-directional.

VI. Results

Analysis outcomes for the individual constructs that yielded significant findings are presented. There were no significant administration or interaction effects for financial, college mentor influence, and doing social good as motivation to study engineering. The same was true for the perceived importance of professional and interpersonal skills, and the satisfaction with instructors constructs. Therefore, those constructs are not discussed below.

The graphs display how construct scores vary across administrations for the different groups, and the discussion outlines the statistical significance of the trends and their implications at a construct level. The construct scores, normalized from 0 to 1, are plotted on the y-axis. Standard error bands are included in the graphs as a visual explanation of how the small group sizes produced large error estimates which then diminished the power of the repeated measures ANOVAs to detect statistically significant effects.

Since missing data were handled via list-wise deletion, the number of subjects within each study group tend to differ slightly for each repeated measures analysis that was conducted for a given construct. However, the variation was not significant; in general, missing responses were less than 10 for the persister group and 1 for the non-persister groups for any given construct. The only exception was construct 11. The significant amount of missing data for construct 11 was associated with the nature of the survey questions; they prompted participants to disclose their engagement in engineering and non-engineering related courses. If a participant had not taken courses falling under those categories during that semester, he/she was instructed to choose the "not applicable" option, in which case it was treated as a non-response.

The slight variation due to missing data presented a dilemma in choosing what data to plot; when group membership changes due to the deletion of subjects from a repeated measures analysis, the means and standard errors of the construct scores change as well. For instance, between administrations 1 and 2, 14 NP4s might have responded to a given construct, so the administration 1↦2 repeated measures analysis includes 14 NP4s-together with the rest of the subjects who were still in the study by administration 2. However, if one of those 14 NP4s missed the third administration of the survey, for the administration 1↦3 repeated measures analysis, the entire set of responses of that NP4 subject were deleted from the dataset, including his or her responses to administrations 1 and 2. Therefore, the mean construct score plots of NP4s over time differ slightly depending on which repeated measures analysis outcomes are plotted.

The plots displayed below are based on group membership at the very last time point relevant to each group. This means the NP2 plots include only the NP2s who responded to the construct during all of the administrations that were applicable to NP2s (administrations 1 and 2); the NP3 plots include only the NP3s who responded to the construct during all of the administrations that were applicable to NP3s (administrations 1, 2, and 3); the NP4 plots include only the NP4s who responded to the construct during all of the administrations that were applicable to NP4s (administrations 1, 2, 3, and 4); and the persister plots include only the persisters who responded to the construct during all of the administrations of the survey.

It is important to note that this choice of what to include in the plots does not mean that only the subjects who responded to a given construct during all of the administrations that were applicable to that group were analyzed. Subjects who missed the latter surveys were still included in the repeated measures analysis that was done up to the time point associated with their missing responses; they just are not reflected in the plots. Reflecting their responses in the plots would have meant including 4 different plots per construct, which would not have been practical.

A. Persistence in Engineering: Academic Persistence

The patterns of student responses are different from the onset depending on group membership (Figure 1). The repeated measures ANOVA revealed a significant administration effect (Wilks' lambda = 0.968, $p < 0.05$) and a significant interaction effect (Wilks' lambda = 0.895, $p < 0.01$).

Based on the *post hoc* polynomial test of trend over the administrations, persisters showed a positive trend in Academic Persistence over the semesters they were enrolled (Wilks' lambda = 0.755, $p < 0.001$). Students who left engineering after the second administration show a negative trend in their Academic Persistence (Wilks' lambda = 0.515, $p < 0.05$), and so did students who left engineering after the third or fourth administration (Wilks' lambda = 0.157, $p < 0.01$, Wilks' lambda = 0.195, $p < 0.005$, respectively).

In addition, the one-way ANOVA conducted at each administration showed that Academic Persistence was significantly lower for NP2s than for persisters starting with the very first administration ($p < 0.05$). By the second administration, the differences between persisters and the non-persister groups widened with persisters scoring consistently higher than the other groups. Differences in Academic Persistence scores were significant between persisters and NP2s ($p < 0.001$), significant between persisters and NP3s ($p < 0.01$), and approached significance between persisters and NP4s (p = 0.056). By the third administration, the differences between persisters and NP3s, and between persisters and NP4s are significant ($p < 0.001$), and by the fourth administration, the difference between persisters and NP4s becomes significant ($p < 0.001$).

There are also significant differences between various non-persister groups at most administrations. NP4s have higher academic persistence scores than NP2s at the second administration ($p < 0.01$) and higher scores than NP3s at the third administration ($p < 0.001$).

B. Persistence in Engineering: Professional

As is the case for the academic persistence construct, the patterns of student responses are different from the onset depending on group membership for the professional persistence construct (Figure 2). The repeated measures ANOVA revealed an interaction effect (Wilks' lambda = 0.941, $p < 0.05$). Moreover, one-way ANOVA at the third administration yielded a significant difference between persisters and NP4s ($p < 0.01$) and NP3s ($p < 0.01$). There was no administration effect for all students pooled, however, when only persisters are considered, repeated measures analysis revealed an administration effect (Wilks' lambda = 0.876, $p < 0.05$).

Unlike the academic persistence construct, there was no mechanism for evaluating students' *actual* professional persistence since the study did not follow the subjects into the professional life. Regardless, the intention of non-persisters to pursue a professional engineering career is lower than persisters, whereas the intention of persisters increases throughout their education.

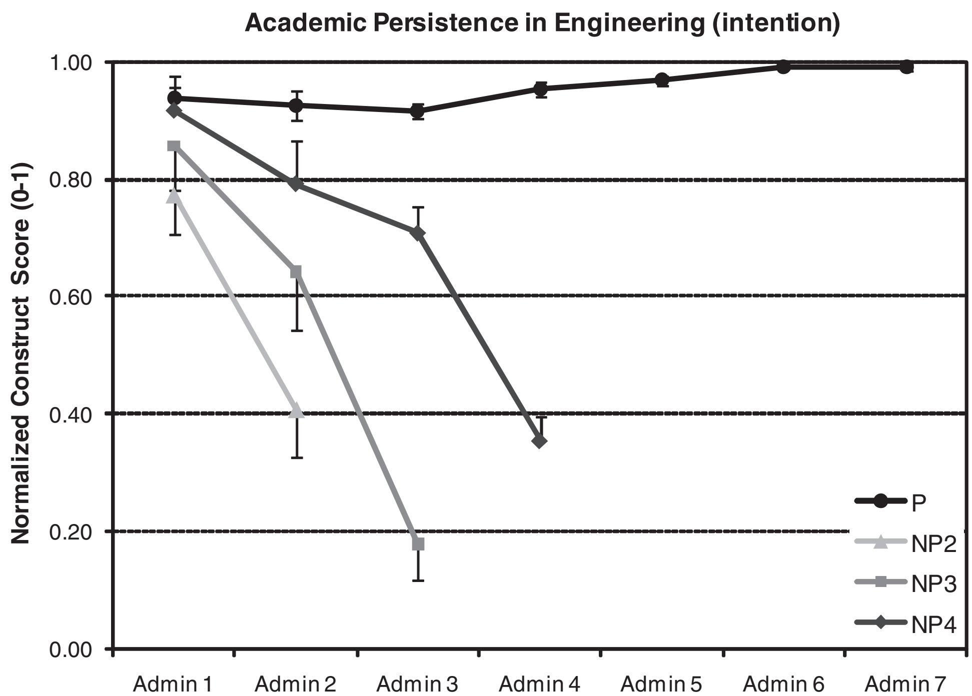

Figure 1. Academic persistence (intention) construct scores vs. administration.

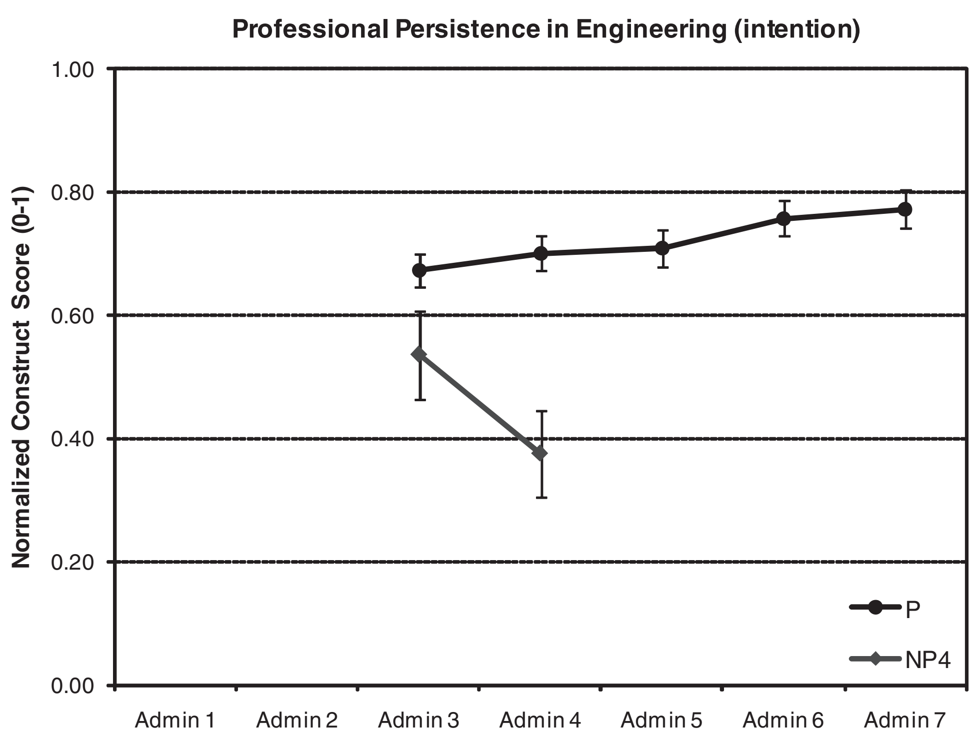

Figure 2. Professional persistence (intention) construct scores vs. administration.

C. Motivation to Study Engineering: Parental Influence

Within the persisters, there is a sharp drop in reported motivation due to parental influence after the second administration (see Figure 3). Repeated measures ANOVA suggests both an administration (Wilks' lambda = 0.931, $p < 0.05$) and an interaction effect (Wilks' lambda = 0.886, $p < 0.05$). The drop coincides with a change in one of the survey items associated with this construct from, "my parents

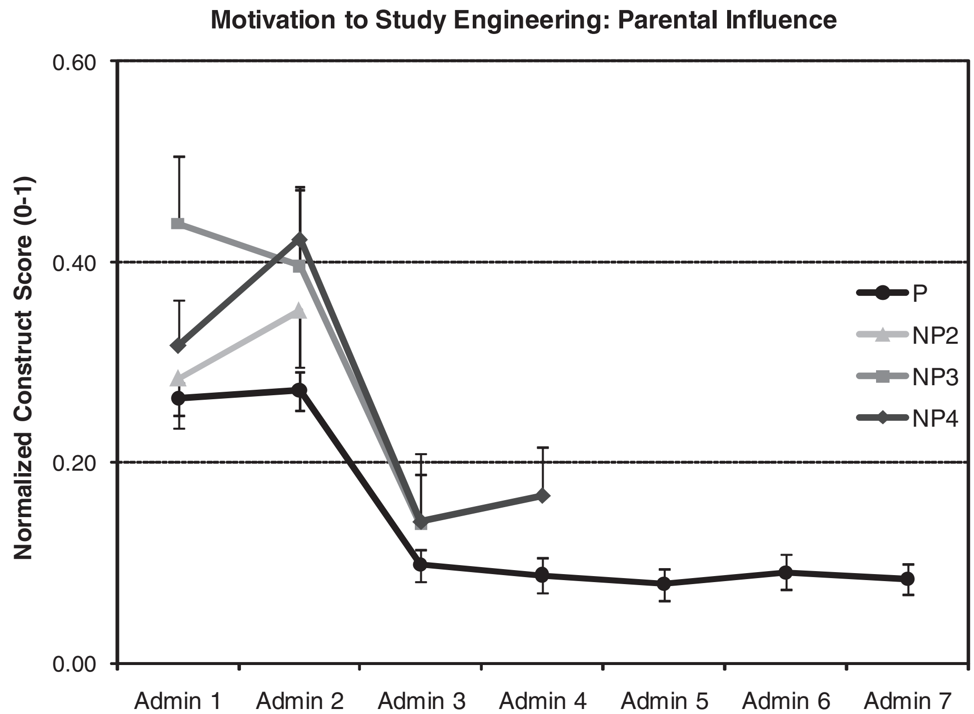

Figure 3. Parental influence as a motivation to study engineering construct scores vs. administration.

are making me study engineering," to "my parents would disapprove if I chose a major other than engineering." At first glance, the sharp fall in average construct scores appears to be an artifact of the construct item composition change. However, given the much milder form of the revised phrasing, the change should have elicited *more* agreement among respondents, rather than less. Therefore, the decline is most likely real, and that the degree to which students are motivated by parental influence drops sharply after the first year of college.

Moreover, there is some evidence that NP3s and NP4s may be slightly more motivated by parental influence than persisters. At the first administration, the value for NP3s was greater than for persisters ($p < 0.05$). Similarly, at the second administration, the value for NP4s was greater than for persisters ($p < 0.05$). No other statistically significant differences were observed.

D. Motivation to Study Engineering: High School Mentor Influence

In contrast to parental influence, there is evidence that high school mentor influence as a motivator to study engineering may have a positive effect on persistence. Participants were only asked about being influenced to study engineering by high school mentors once, at the second administration; measuring this construct over time would not have been particularly useful since the postulated influence was in the past. A one-way ANOVA by group at the second administration has an overall p-value of 0.083. The scores are highest for the groups that stayed in engineering the longest (see Figure 4); in fact, the means are ranked in order by longevity in the program (P > NP4 > NP3 > NP2); the mean score of the persisters is significantly higher than the NP2 mean ($p < 0.05$).

E. Confidence in Math and Science Skills

Repeated-measures ANOVA does not indicate any significant interaction or administration effects for this construct when all groups are considered (see Figure 5). There is an administration effect for persisters only (Wilks' lambda = 0.713, $p < 0.001$). However, this administration effect may be an artifact of the item composition change that occurred at the third administration for this construct.

One-way ANOVA indicates that NP2s report lower confidence than persisters at each of first two administrations ($p < 0.05$), that NP3s report lower confidence than persisters at each of the first three administrations ($p < 0.07$), and that NP4s report lower confidence than persisters at each of the first four administrations ($p < 0.05$). This suggests that non-persisters are less confident in their math and science skills than persisters despite the non-significant results of the repeated-measures analysis.

F. Confidence in Professional and Interpersonal Skills

Repeated measures ANOVA indicates a strong administration effect for persisters only (Wilks' lambda = 0.468, $p < 0.001$); their confidence in professional and interpersonal skills increases steadily over time (see Figure 6). When all groups are considered, there is also an administration effect (Wilks' lambda = 0.927, $p < 0.01$). Note that there has been a minor item composition change for this construct at the third administration, which might have factored into the increase from administration 2 to administration 3.

There is no evidence of differences between the persister and non-persister groups at individual administrations, which contrasts with the confidence in math and science skills construct.

G. Confidence in Solving Open-Ended Problems

Repeated measures ANOVA indicates administration effects when NP3, NP4, and P groups are considered together (Wilks lambda = 0.945, $p < 0.05$). This administration effect is stronger when

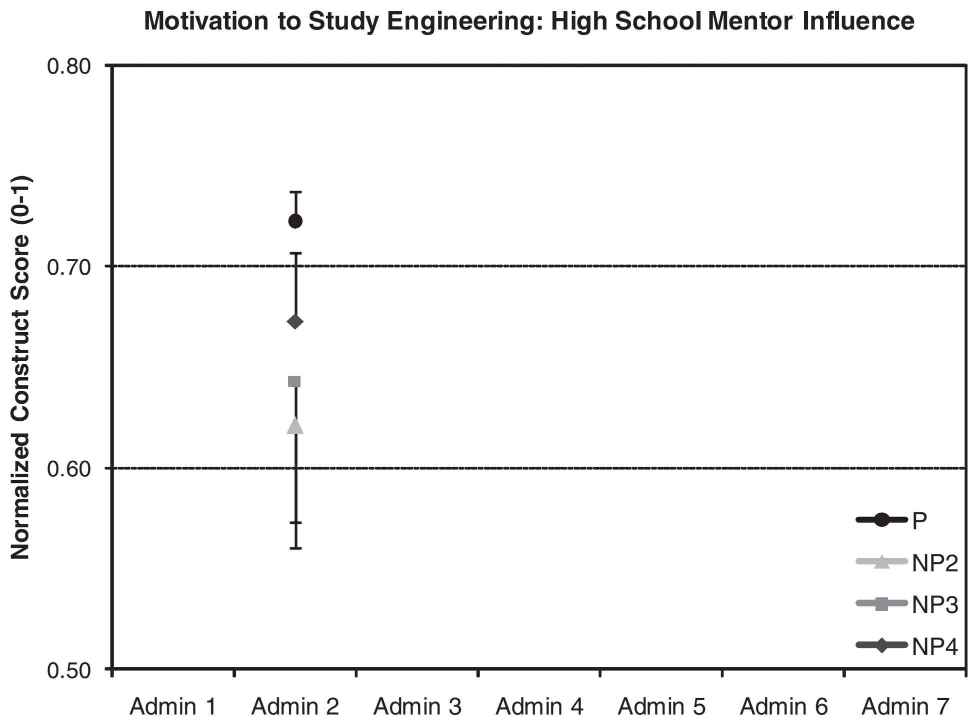

Figure 4. High school mentor influence as a motivation to study engineering construct scores at the second administration.

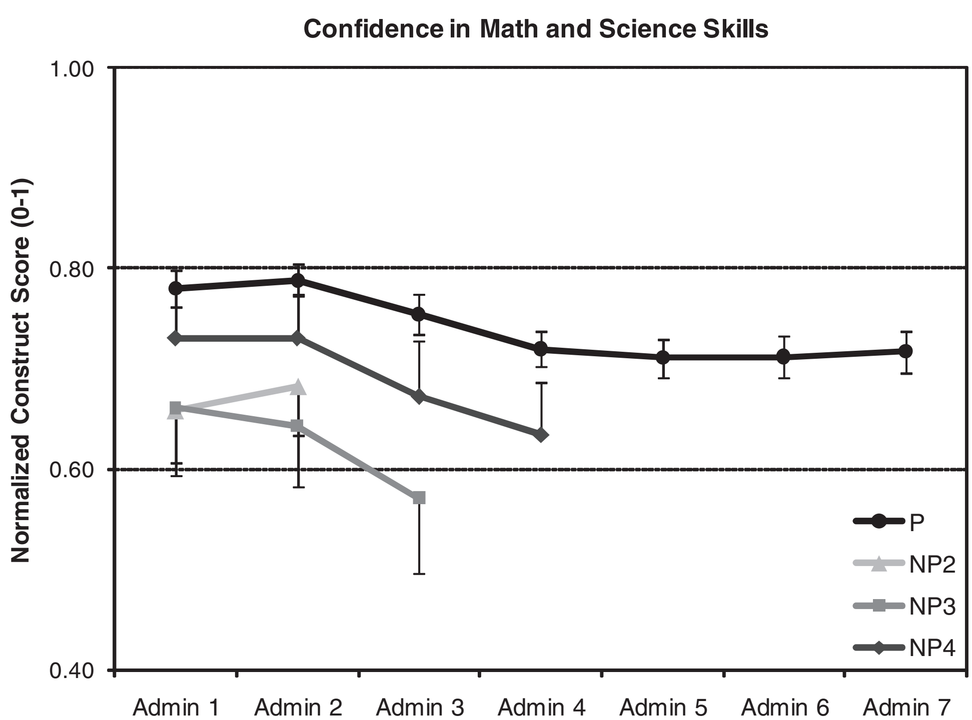

Figure 5. Confidence in math and science skills construct scores vs. administration.

only persisters are considered (Wilks' lambda = 0.789, $p < 0.01$). There are no significant interaction effects between the groups (see Figure 7). These results suggest that confidence in solving open-ended problems does change over time, and for persisters, the trend seems to be a dip in confidence during the junior year, which is followed by an increase in the senior year.

H. Perceived Importance of Math and Science Skills

Repeated measures ANOVA does not indicate any administration or interaction effects for all groups (see Figure 8). However, there is an administration effect for persisters only (Wilks' lambda = 0.693, $p < 0.001$). Cross administration t-tests provide some evidence that the responses of persisters possibly peak at administrations 4 and 5; the

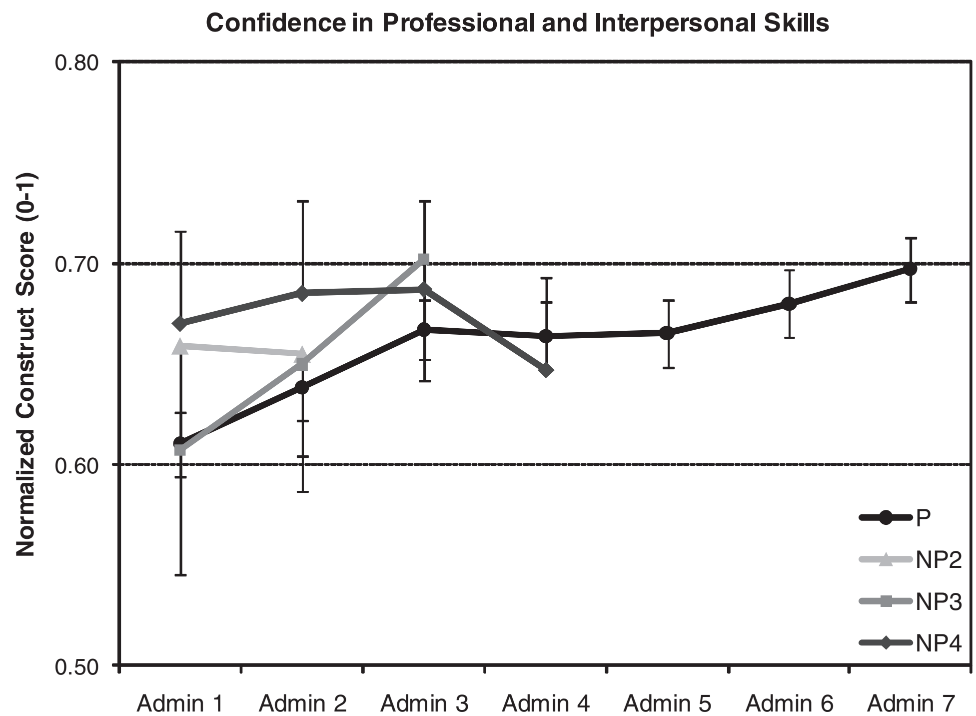

Figure 6. Confidence in professional and interpersonal skills construct scores vs. administration.

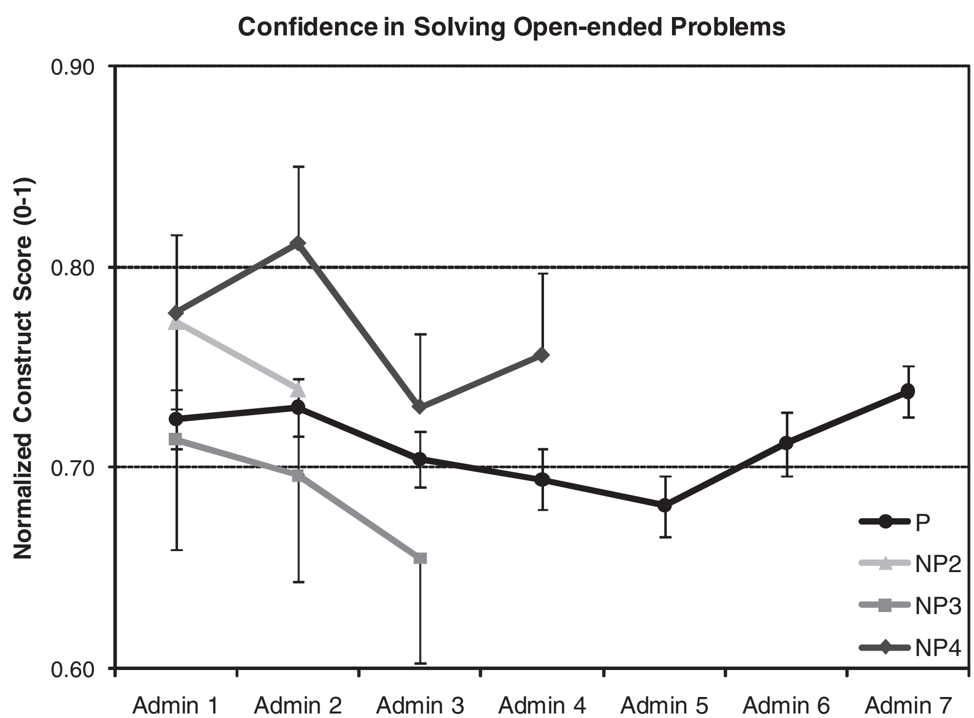

Figure 7. Confidence in solving open-ended problems construct scores vs. administration.

values at these times were higher than at administration 6 ($p < 0.05$ vs. administration 4, $p < 0.01$ vs. administration 5). However, this evidence is fairly weak. Note that the scores on the first two administrations are higher than the other five ($p < 0.05$); this is most likely an artifact of the significant item composition change to this construct that occurred at administration 3.

I. Knowledge of the Engineering Profession

Repeated measures ANOVA indicates administration effects for all groups (Wilks' lambda = 0.878, $p < 0.001$), and persisters only (Wilks' lambda = 0.255, $p < 0.001$). All groups report a clear and steady increase in self-reported knowledge of the engineering profession (see Figure 9). One-way ANOVA also

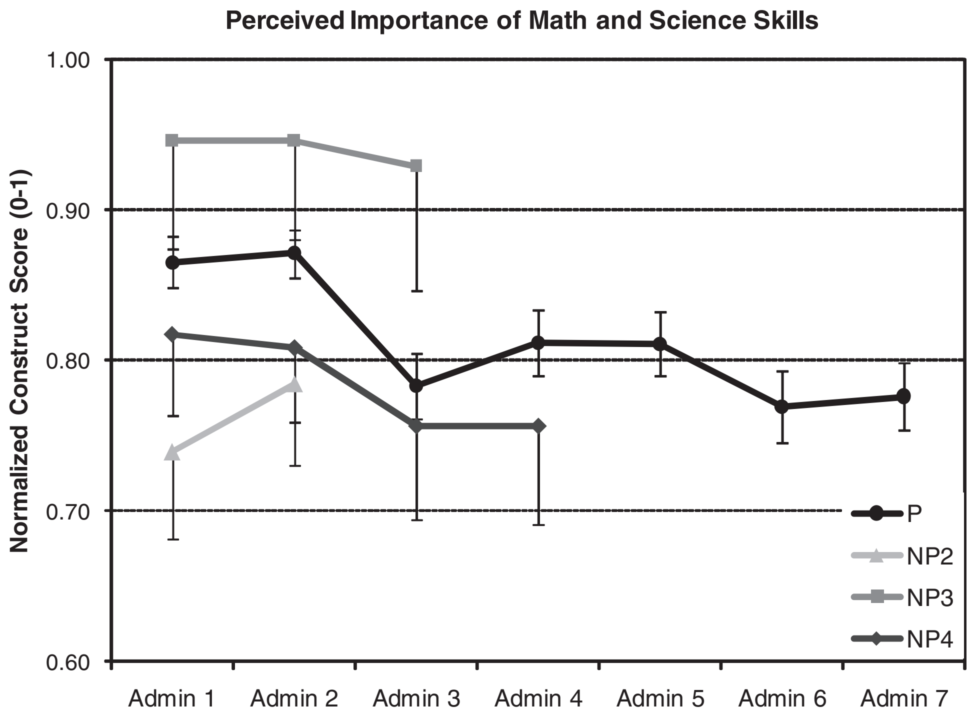

Figure 8. Perceived importance of math and science skills construct scores vs. administration.

suggests that the non-persisters were statistically indistinguishable from the persisters.

Note that the response resolution was changed from a 4-point to a 5-point scale at the third administration, which might have contributed to the increase in response values from administration 2 to administration 3.

J. Exposure to Project Based Learning (Individual Projects)

Repeated measures ANOVA does not indicate any administration or interaction effects for all groups. However, there is an administration effect for persisters only (Wilks' lambda = 0.760, $p < 0.001$); their reported exposure to project based learning increases over time (see Figure 10).

One-way ANOVAs reveal significant differences at the second administration between persisters and NP4s ($p < 0.01$) and between NP4s and the other non-persister groups ($p < 0.05$). At the third administration, NP3s and NP4s remain different ($p < 0.01$), and at the fourth administration NP4s are different than persisters ($p < 0.01$).

Therefore, there is a clear difference between the trends exhibited by NP3s and NP4s over time although it is difficult to identify that as a distinct pattern in the absence of a pronounced relationship between non-persisters and persisters.

K. Exposure to Project Based Learning (Team Projects)

Comparison of the graphs for exposure to project-based learning through individual and team projects reveals that they are qualitatively similar. Repeated measures ANOVA does not indicate any administration or interaction effects for all groups. However, there is an administration effect for persisters only (Wilks' lambda = 0.355, $p < 0.001$); persisters' exposure to team projects increases over time (see Figure 11).

For persisters, cross-administration t-tests show that the reported exposure is level until after administration 4 (the scores for the first three administrations are statistically indistinguishable from each other). After this point, the reported exposure begins to rise rapidly and the mean construct scores for administrations 5, 6, and 7 differ from all other time points.

One-way ANOVAs reveal significant differences at the first administration between persisters and NP2s ($p < 0.05$), and between all of the non-persister groups ($p < 0.05$). At the second administration, although there is a significant overall difference between the groups ($p < 0.05$), there are no significant differences between any two specific groups. However, these findings do not point at any specific trends.

L. Frequency of Involvement in Extra-Curricular Activities

Repeated measures ANOVA does not indicate any administration or interaction effects for all groups. However, there is an administration effect for persisters only (Wilks' lambda = 0.741, $p < 0.001$); persisters report that their involvement in extra-curricular activities drops in their junior year and then rebounds during their senior year (see Figure 12). One-way ANOVA does not reveal any differences between groups at any administration.

Note that although there were NP3 responses to this construct, they could not be included in the repeated measures analysis since, by definition, responses of a group at a single time point cannot be analyzed from a longitudinal perspective. The same consideration applies to all other constructs that are measured beginning administration 3.

M. Perceived Importance of Extra-Curricular Activities

Repeated measures ANOVA does not indicate any administration or interaction effects for all groups. However, there is an administration effect for persisters only (Wilks' lambda = 0.693,

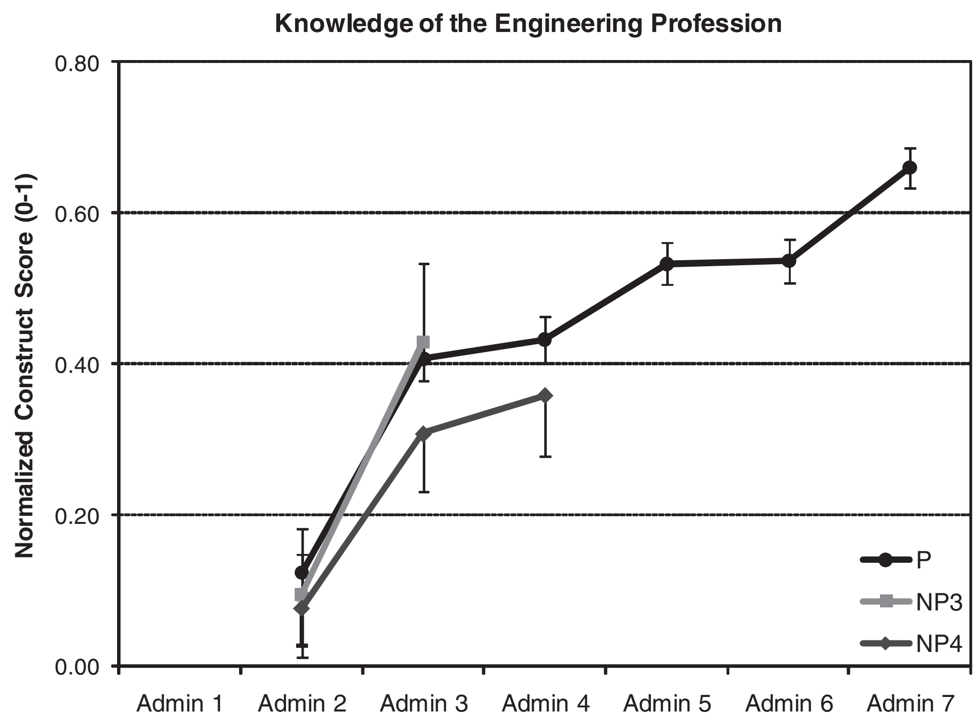

Figure 9. Knowledge of the engineering profession construct scores vs. administration.

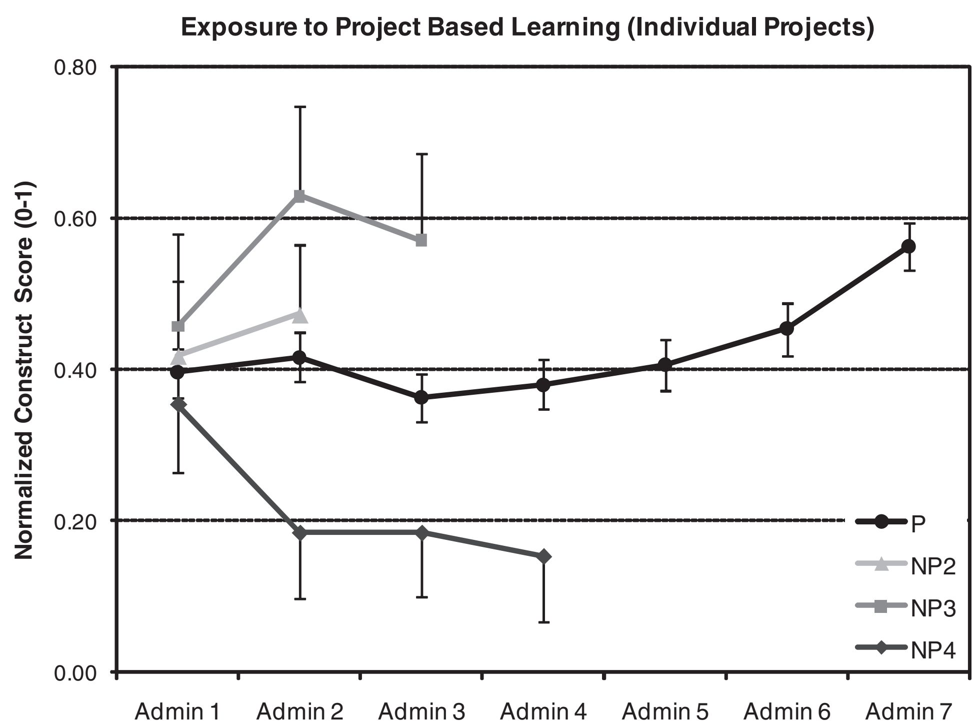

Figure 10. Exposure to project-based learning through individual projects construct scores vs. administration.

$p < 0.001$). For persisters, the perceived importance of extracurricular activities peaks during the junior year (Figure 13).

Comparing these findings to the findings from the previous construct, the interval (junior year in college) when persisters reported the highest perceived importance of extracurricular activities corresponded closely with the interval when they reported the lowest frequency of engaging in these activities; the two lines mirror each other.

N. Curriculum Overload

Repeated measures ANOVA did not reveal any significant administration or interaction effects although it is interesting to note

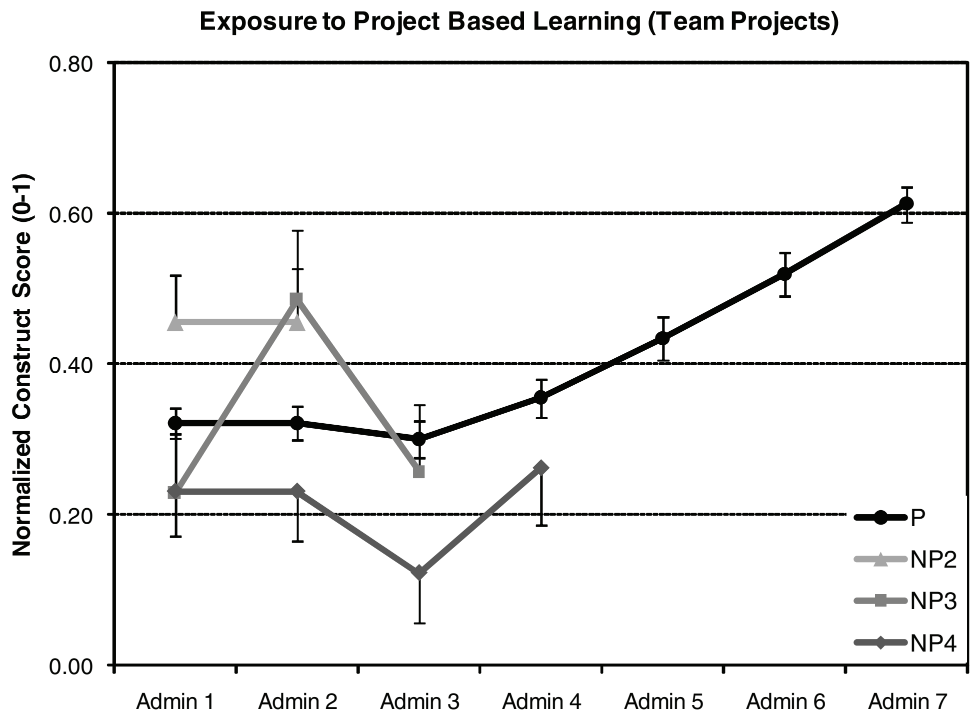

Figure 11. Exposure to project-based learning through team projects construct scores vs. administration.

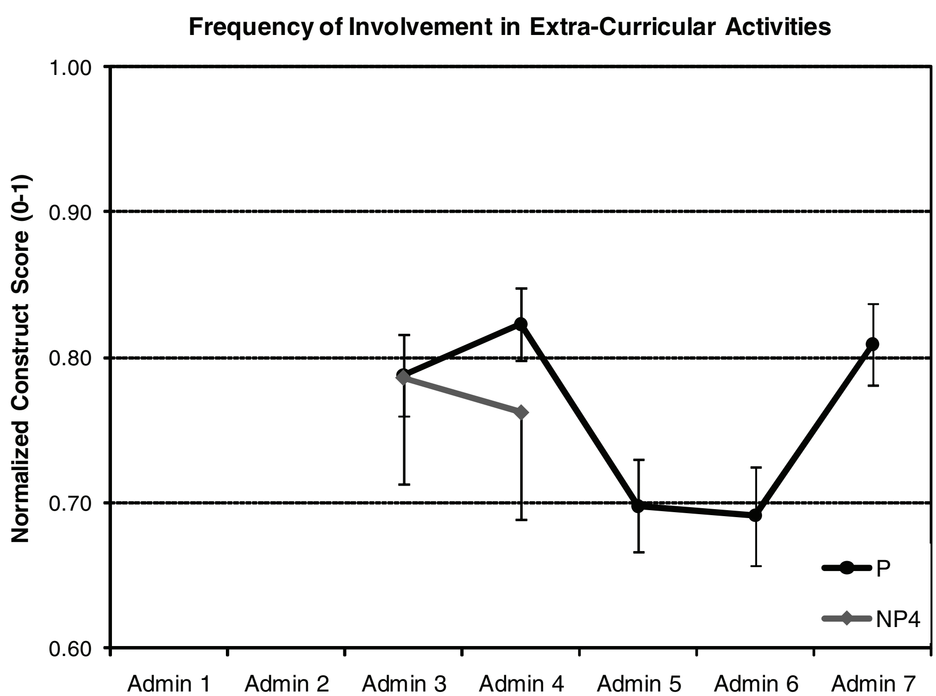

Figure 12. Frequency of involvement in extra-curricular activities construct scores vs. administration.

that the peak mean response to this construct was during the junior year (see Figure 14).

O. Financial Difficulties

Repeated measures ANOVA revealed an interaction effect when NP4 and P groups were considered (Wilks' lambda = 0.940, $p < 0.05$), and an administration effect for persisters only (Wilks' lambda = 0.791, $p < 0.001$).

For persisters, it is not surprising that concerns about financial difficulties impeding the completion of an engineering degree decline steadily with time as graduation nears (see Figure 15). The interaction effect between NP4s and persisters is more difficult to

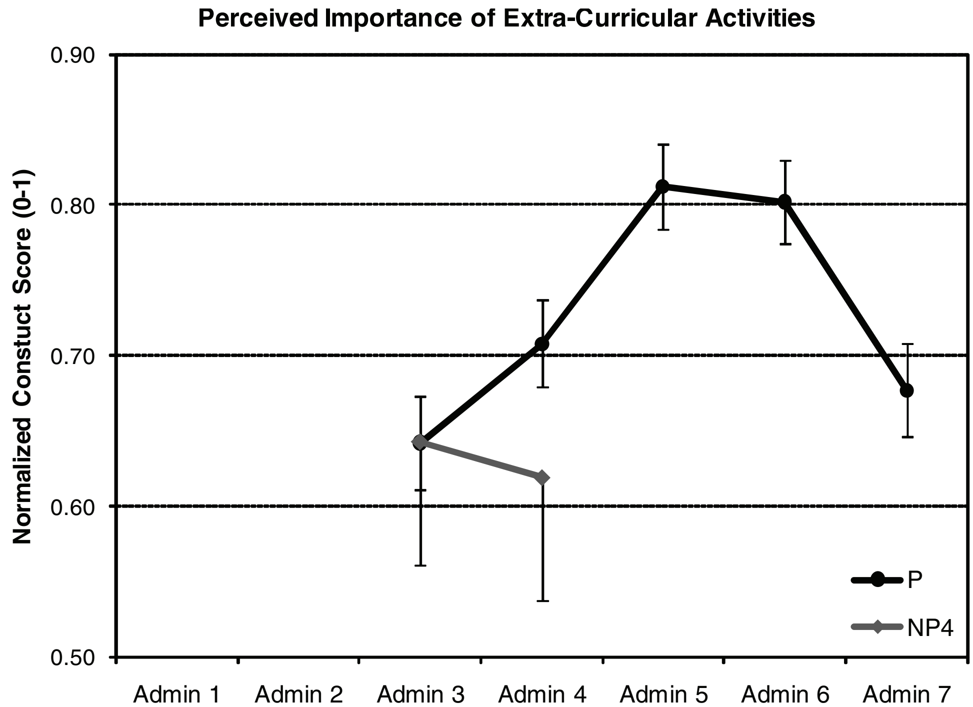

Figure 13. Perceived importance of involvement in extra-curricular activities construct scores vs. administration.

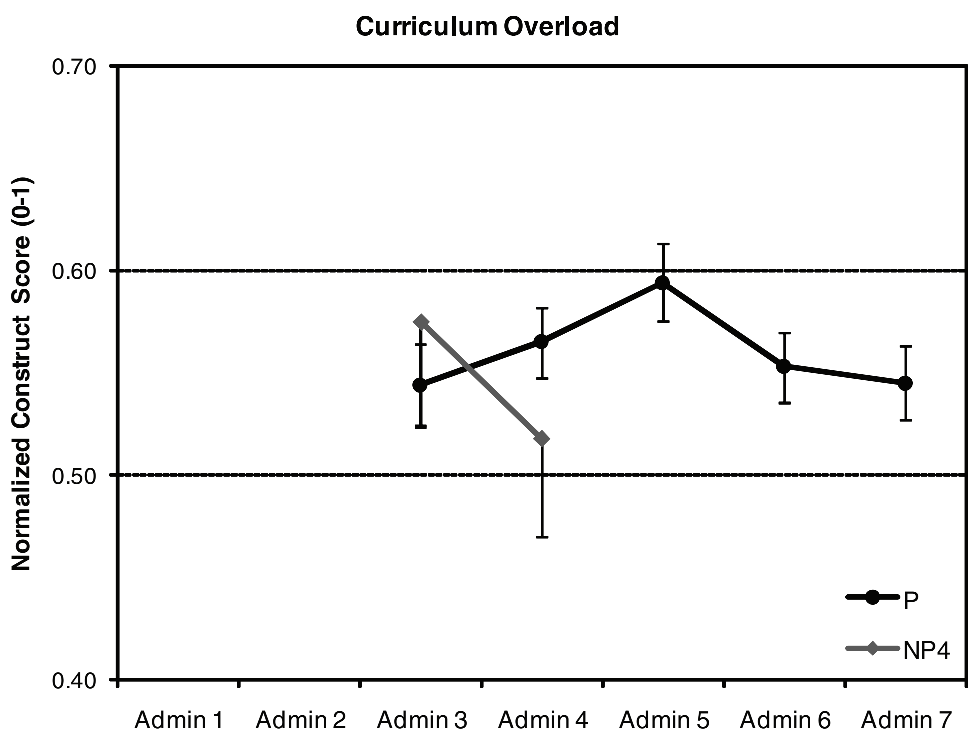

Figure 14. Curriculum overload construct scores vs. administration.

interpret. One-way ANOVA does not reveal any significant differences between the NP4 and P responses at the individual administrations.

In the absence of significant differences at the individual administrations, it is not possible to state that the non-persister group's decision to leave engineering is related to their increasing financial concerns. However, the interaction effect is suggestive of a possible relationship, which should be explored further.

P. Academic Disengagement (Liberal Arts)

Repeated measures ANOVA does not indicate any administration or interaction effects for all groups (see Figure 16). However,

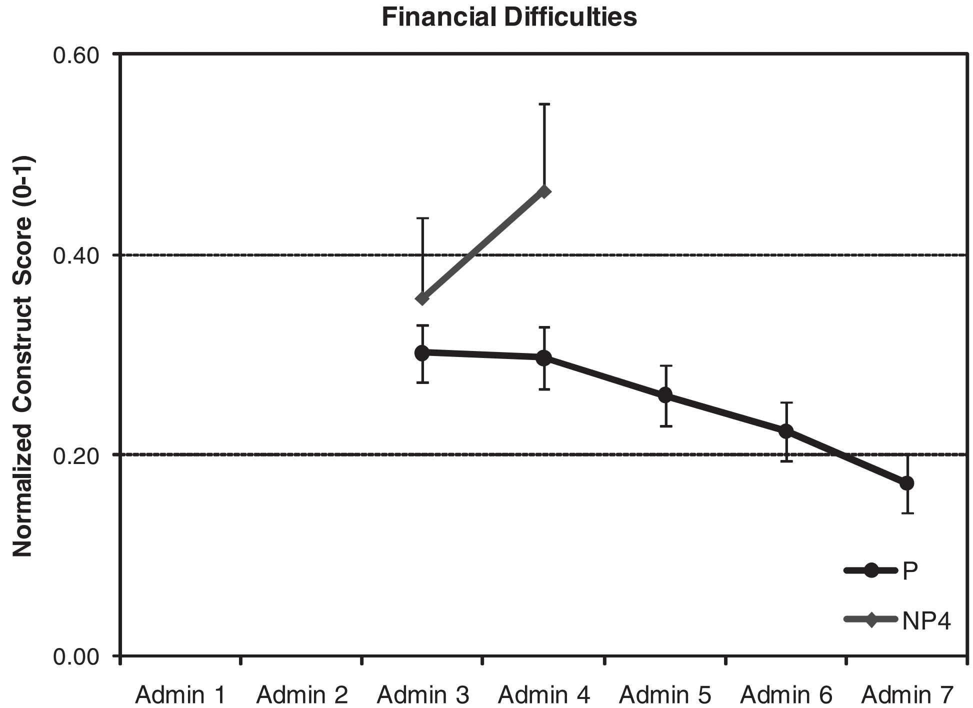

Figure 15. Financial difficulties construct scores vs. administration.

there is an administration effect for persisters only (Wilks' lambda = 0.680, $p < 0.05$) as their disengagement from liberal arts courses increased over the seven administrations. These findings will be considered in detail in comparison with the disengagement from engineering-related courses in the next section.

Q. Academic Disengagement (Engineering Related)

Repeated measures ANOVA for NP2s and Ps (including the 2 NP4s who responded to this construct) reveals an administration effect for disengagement from engineering-related courses (Wilks' lambda = 0.861, $p < 0.01$) as they become increasingly disengaged from engineering related courses over time (see Figure 17). For persisters only, a similar effect exists (Wilks' lambda = 0.309, $p < 0.001$). One-way ANOVA at specific administrations does not indicate a significant difference between NP2 and P responses.

Moreover, due to technical reasons associated with the repeated measures analysis that were described at the beginning of the results section, the number of subjects included in the analysis decreases if there are missing responses to individual administrations—even if the missing responses are sporadic. It is especially important to note that the response options to the items associated with construct included "N/A," which was considered a non-response for the purposes of the repeated measures analysis, since they are related to participants' behavior in engineering-related courses. While not all students take engineering-related courses every semester, this may be particularly applicable to non-persisters who are exploring their options before making the decision to leave engineering. Consequently, for this construct, there were an unusually low number of non-persisters that could be included in the repeated measures analysis for this construct (8 NP2s, 0 NP3s and 2 NP4s), which resulted in the lack of NP3 and NP4 lines in Figure 17. However, there were at least 11 NP2, 3 NP3 and 10 NP4 responses at each time point.

An alternative analysis was performed with those data, where the means for each group were plotted across the administrations. An overall linearly increasing trend was observed across all groups, suggesting steadily increasing disengagement from engineering related courses-even for the persisters. However, the non-persisters seemed to be disengaging at a higher rate than persisters, whereas the non-persisters seemed to be disengaging at a similar rate when compared to each other. To test this observation, linear regression was performed on each of the non-persister groups and the persister group, and the slopes of the non-persister regression lines were compared with the slope of the persister regression line. The difference was shown to be statistically significant for the NP4 line and P line ($p < 0.05$), although not for the NP2 and NP3 lines

It is somewhat surprising to see persisters increasingly disengage from engineering-related courses. However, they increasingly disengage at a similar rate from liberal arts courses as well. Therefore, the disengagement phenomenon seems to be a general one for persisters.

R. Frequency of Interaction with Instructors

Repeated measures ANOVA does not reveal any significant administration for all groups. There is a significant interaction effect for administrations 1 through 3 (Wilks' lambda = 0.890, $p < 0.05$). When only persisters are considered, there is an administration effect (Wilks' lambda = 0.708, $p < 0.01$); their frequency of interaction increases with time (see Figure 18).

The only significant one-way ANOVA is at the third administration, where NP3s report significantly higher interaction frequencies than persisters ($p < 0.05$).

Since the construct does not make a distinction between the backgrounds of the instructors with whom the students interacted, it is not possible to determine if the increase in the interaction

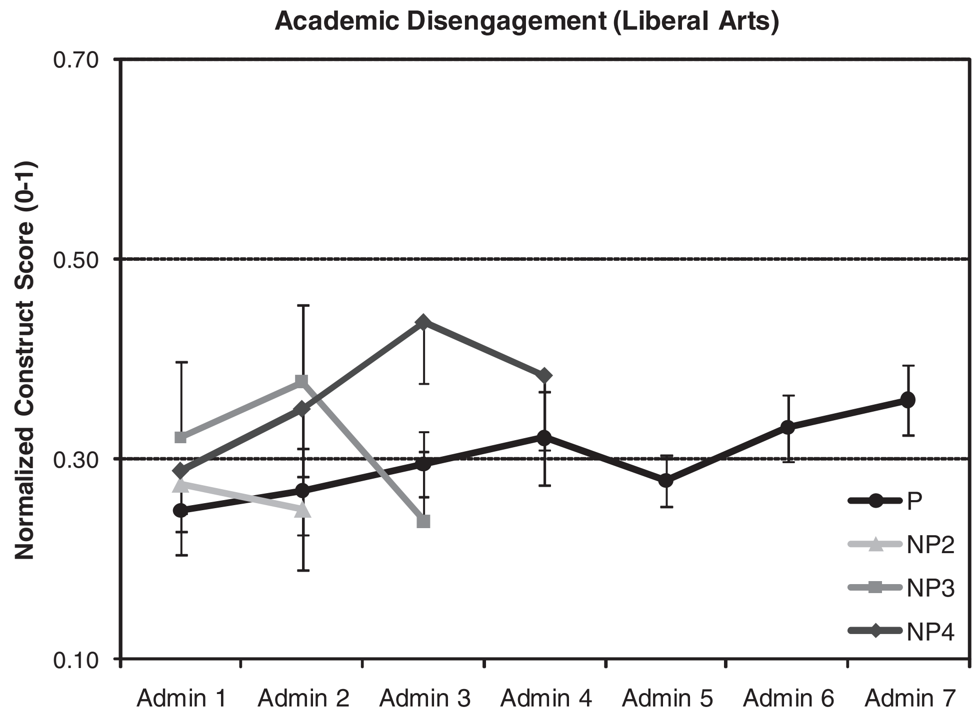

Figure 16. Academic disengagement from liberal arts courses construct scores vs. administration.

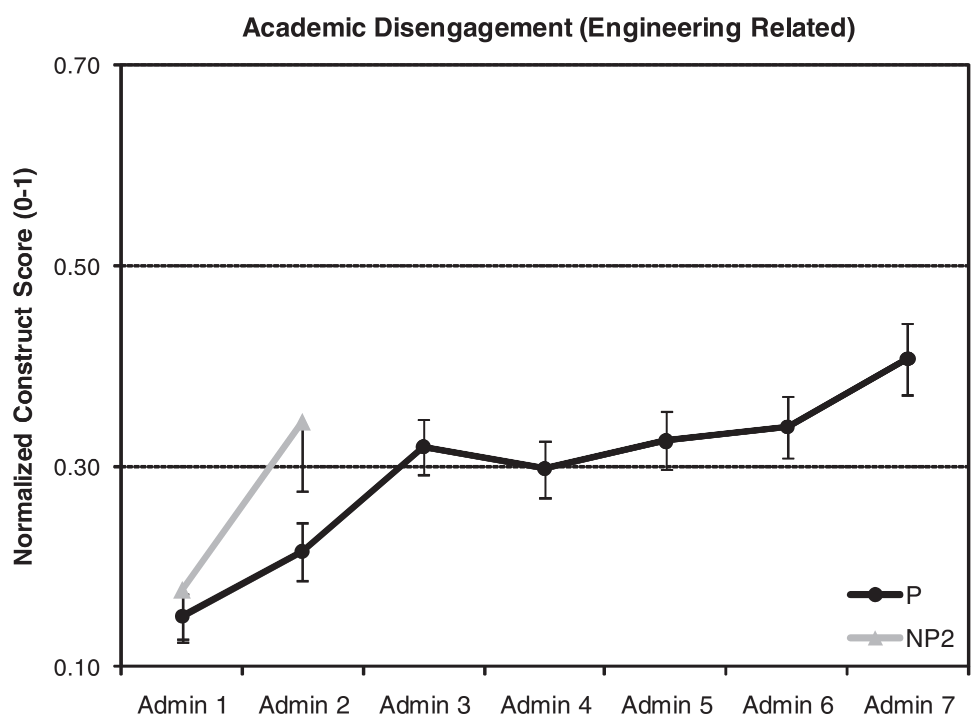

Figure 17. Academic disengagement from engineering related courses construct scores vs. administration.

between the NP3s and instructors is due to the fact that they are possibly interacting with non-engineering faculty more (liberal arts disengagement decreased for NP3s between administrations 2 and 3).

S. Satisfaction with Facilities

Repeated measures ANOVA does not reveal any administration or interaction effects for all groups. However, there is an administration effect for persisters only (Wilks' lambda = 0.727, $p < 0.01$); persisters'

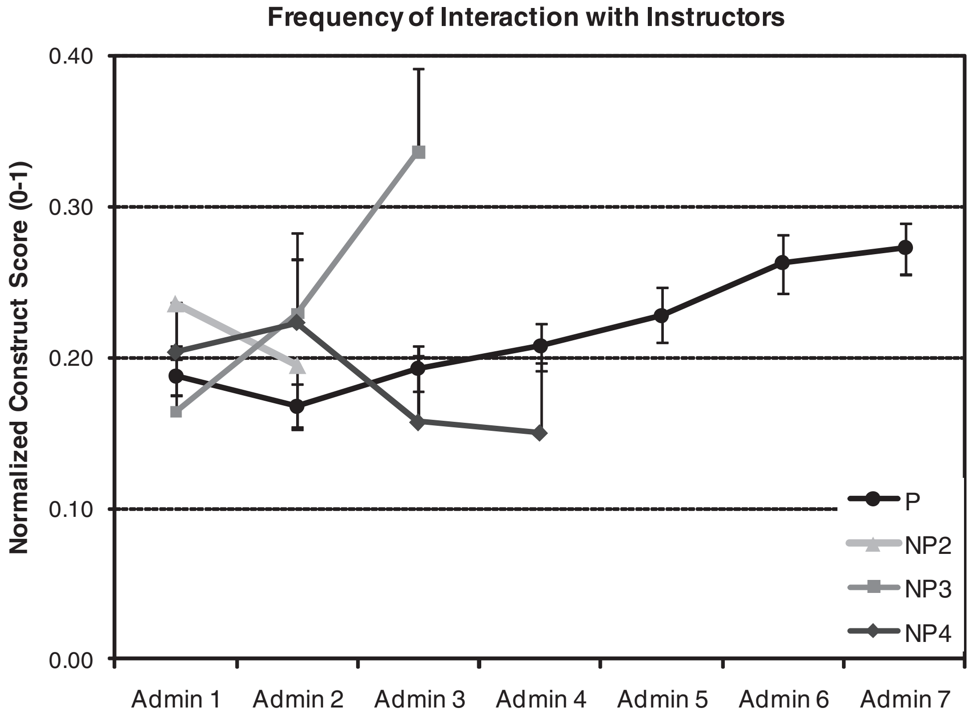

Figure 18. Frequency of interaction with instructors construct scores vs. administration.

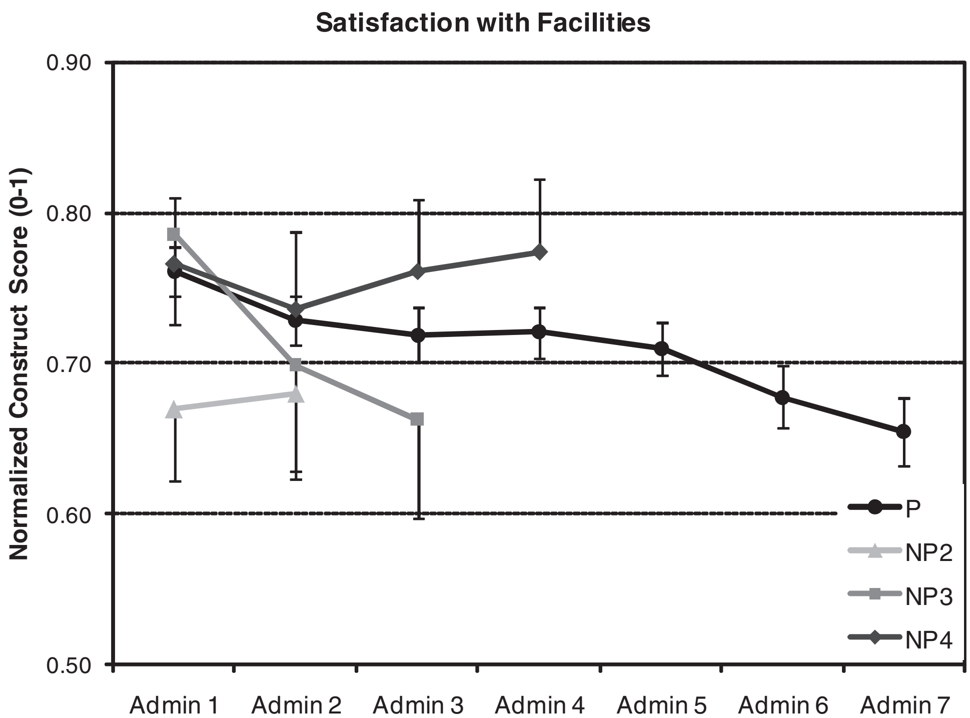

Figure 19. Satisfaction with facilities construct scores vs. administration.

satisfaction with facilities decreases with time (see Figure 19). There are no differences between groups at any of the administrations.

T. Overall Satisfaction with Collegiate Experience

Repeated measures ANOVA reveals an administration effect for all groups (Wilks' lambda = 0.907, $p < 0.05$). An administration effect is also present for persisters only (Wilks' lambda = 0.563, $p < 0.01$). These administration effects seem to be related to the drop experienced by persisters and non-persisters in administration 4, which, for persisters, is followed by an increase in administrations 5 and 7 (Figure 20).

One-way ANOVA indicates that NP4 responses are significantly lower than persisters' responses at the fourth administration.

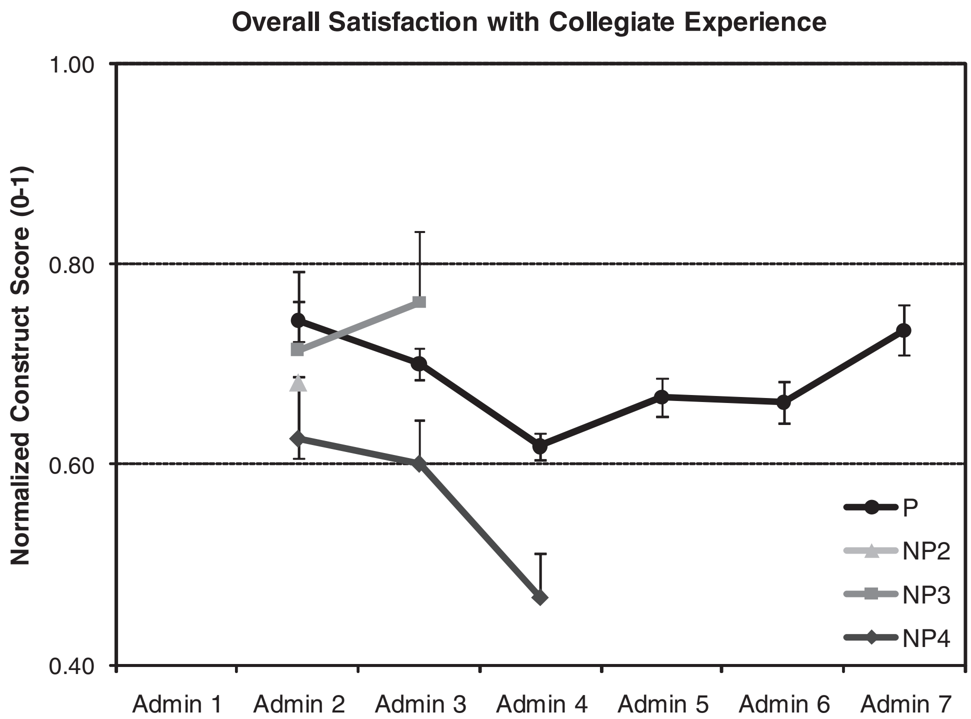

Figure 20. Overall satisfaction with collegiate experience construct scores vs. administration.

However, there are no significant differences between persister and non-persister groups at the other administrations. Therefore, it is not possible to identify a trend.

VII. Discussion

This section compares and contrasts persisters and non-persisters, and considers how persisters develop over their four years of college in light of the results presented above.

A. Differences Between Persisters and Non-Persisters

For many of the constructs investigated here, the responses from persisters and non-persisters are indistinguishable during the students' first years in college. This overall finding is consistent with what Seymour and Hewitt reported (Seymour and Hewitt,1994, 1997). Moreover, as students progress through their undergraduate education, the future persisters and non-persisters ascribe comparable importance to and confidence in professional and interpersonal skills, report indistinguishable levels of financial motivation to study engineering and knowledge of the engineering profession, and display similar confidence in solving open-ended problems. They also report comparable frequency of interaction with instructors, and similar satisfaction with these instructors. Therefore, by these measures, it might be difficult to spot a student moving away from engineering, as compared to a student who is likely to persist.

However, they are not similar when viewed through some of the other constructs. We see that non-persisters are more motivated to study engineering by parents than persisters, whereas persisters are more motivated by a high school mentor. In addition, non-persisters appear to be less confident in their math and science skills. We note that Besterfield-Sacre et al. (1997) also flagged confidence in engineering and science skills as being lower among first-year non-persisters who left engineering in good academic standing. Furthermore, the evidence suggests that non-persisters might be more concerned with financial difficulties than persisters.

Finally, persisters and non-persisters are strikingly different in their *own* perception of whether they will graduate with an engineering degree or enter professional practice, which declines sharply for non-persisters compared to persisters. Early non-persisters, students who decide to leave engineering sooner than other non-persisters, are less firm in their intentions even in their first year of college, and this difference widens and becomes applicable to late non-persisters as well with time.

B. Differences Among Non-Persisters

When only the non-persisters are considered, we see that early non-persisters express lower intentions to study engineering from the very beginning. This suggests that doubt about engineering as a major for some non-persisters may be present from matriculation, intensifying over their first year of college, whereas for other non-persisters, it might develop more gradually. If that is the case, it may be that the sources and substance of these doubts are also different. Therefore, it appears that "time" may be another factor (in addition to those suggested by Adelman, 1998; Besterfield-Sacre et al., 2001; Huang, Taddese, and Walter, 2000; Seymour and Hewitt, 1997) in understanding persistence in completing an engineering degree.

The data also suggest that there might be some additional differences between non-persister groups. Two constructs in which such potential differences might exist are influence of high school mentors on motivation to study engineering and confidence in math and science skills. For these construct scores, examination of means for each non-persister group shows that there is a general trend where the means for the non-persister groups are ranked in order by longevity in engineering education at almost each administration. Although there is no statistical difference between the reported differences (most likely due to low statistical power associated with small sample sizes), the trends are too uniform to dismiss as chance, and these observations should be explored further with a study design that allows for higher numbers of subjects in each non-persister group.

C. Academic Pathways of Persisters

As persisters move from their first to their fourth year of college, their coursework involves increasing levels of individual and team-based projects. These students also interact more with instructors. It would seem reasonable to expect that these students would be more academically engaged; but, surprisingly, we found this not to be the case. Seniors are more academically *disengaged* in both their engineering and liberal arts courses than are first-year students.

At the same time, as their college career progresses, persisters become more committed to completing their engineering degree and to entering into engineering work after they graduate, which is desirable from the point of view of curricular effectiveness if the changes can be attributed to their academic experiences. We also see steady increases in students' self-reported gains in engineering knowledge, and in their confidence in professional and interpersonal skills. It is interesting to note that this increase in professional/interpersonal confidence is not accompanied with an increase in perceived importance of these skills; these students as seniors are no more convinced of the importance of these skills than when they were first-year students.

The first-year to senior changes just described among the 107 persisters studied longitudinally with the PIE instrument have been replicated with the similar APPLE survey, as administered cross-sectionally to over 4,500 engineering students at 21 universities across the U.S. (Sheppard et al., 2010).

Two constructs where the PIE and APPLES instruments show different trends are concerns about financing college, and overall satisfaction with college. Among the PIE persisters, there is a steady decrease from first-year to senior year in concerns about financing college, whereas with APPLES respondents, seniors are as concerned as first-year students. When we compare PIE seniors and first-year students—the same group of people—they have comparable levels of overall satisfaction with college, whereas with APPLES respondents, seniors are less satisfied than are first-year students. Both of these differences between PIE and APPLES may reflect differences in the sampling strategies used in APPLES, which was a cross-sectional study. For example, proportionally more APPLES respondents were part-time or first-generation college students than in PIE. In addition, the potential for the Academic Pathway Study to affect the 160 students involved in longitudinal PIE study needs to be acknowledged; might the data collection process itself have served as a positive intervention?

There are several constructs that have curious "bumps" or "dips" in the middle years of the college experience of the PIE persisters. Confidence in open-ended problem solving decreases steadily from first-year to the beginning of junior year, then rises. Frequency of involvement in extracurricular activities dips markedly during the junior year; at the same time perceived importance of these activities is at a peak (Figures 12 and 13, respectively). This suggests that students value these activities the most when they are least engaged in them. This is bolstered by the observation of a similar rise in curriculum overload (Figure 14) at these time points, although note that this rise is not statistically significant. At many schools, the junior year is the time when students become deeply engaged with courses in their engineering field, and the decrease in extracurricular activity may reflect that.

We cannot explain these phenomena with confidence, but do flag them as an indication of potentially interesting changes that occur as engineering students transition from their first two years (often foundational or "pre-engineering" years) to being full-fledged members of an engineering discipline.

Finally, although the PIE data do not allow us to investigate the possibility of causal relationships, it is interesting to note the steady increase in the exposure to project-based learning via team projects and knowledge of the engineering profession construct responses of the persisters. It can be argued that these constructs are linked from a pedagogical perspective, and further exploration of relationships between these two constructs would be worthwhile.

VIII. Conclusions

In this paper, we considered how students who enter college with an intention to study engineering change during their undergraduate career according to several relevant constructs developed from published findings on engineering student retention as well as our own thinking and experience. This investigation was unique in the sense that it utilized a longitudinal approach over the course of a relatively long period—four years—and yet possessed the necessary resolution to identify the intervals in which some participants decided not to major in engineering.

While the small sample size does not allow us to extensively generalize from the findings, the longitudinal results reiterate some key findings that have been reported in the literature. For example, in this study, persisters and non-persisters do not differ significantly according to the majority of the constructs; analyses of 16 of the 21 constructs did not reveal significant differences. The differences between persisters and non-persisters are, for the most part, subtle. This is consistent with the findings of Seymour and Hewitt (1997).

The PIE findings also provide new insights into academic persistence in engineering, showing that parental and high school mentor motivation to study engineering, and confidence in math and science skills are correlates of persistence in engineering education. This prompts us to ask if the students who do not persist are less likely to have had mentors who were knowledgeable about engineering. And can their lower confidence in math and science skills be addressed through targeted interventions early on during their college experience? For anyone working with pre-college students, mentor encouragement may have long-term consequences. These findings also raise questions about the role of parental influence; why does parental influence seem to act as a de-motivator for non-persisters? How is parental influence viewed by students within the context of early experiences in the undergraduate engineering pathway?

Finally, the findings illustrate that non-persisters' intentions to complete a major in engineering not only decreases in time, but it is significantly less strong than persisters' intention to complete a major in engineering. Since this decline in intention starts a minimum of two semesters before non-persisters actually switch out of engineering, it may be possible for programs to intervene. We are not suggesting that the goal should be to have all students persist in engineering; rather, we are asking how the college experience, particularly in the first semesters, can ensure that students engage in substantive conversations and relevant experiences to inform their decisions to stay or move away from engineering. These conversations and experiences might come from, for example, advising, courses, or extra-curricular involvement.

There are some natural research extensions of the findings of this study. They include connecting the PIE results with structured and semi-structured interview data on these same 141 students to better understand how persisters and non-persisters talk about their experiences with math and science, their interests in engineering, and their use of mentors. Another extension would be to employ survival analysis to build a predictive model based on the PIE data composed of sets of scales for the purpose of estimating probabilities of non-persistence across the undergraduate period; this approach would allow us to identify which students are most at-risk for non-persisting and to identify when in their undergraduate career this risk is greatest.

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APPENDIX

Fall 2005 PIE Survey Constructs, Items, Internal Consistency Reliabilities, and Item-Total Correlations.

Construct and Item Content	Fall 05 Item-Total Correlation	Fall 05 Alpha
1a. Academic Persistence		n/a
Do you intend to complete a major in engineering?	n/a	
1b. Professional Persistence		n/a
Do you intend to practice, conduct research in, or teach engineering for at least 3 years after graduating?	n/a	
2a: Motivation (financial)		0.76
Engineers are well paid.[1]	0.74	
Engineers make more money than most other professionals.[1]	0.69	
An engineering degree will guarantee me a job when I graduate.[1]	0.40	
2b. Motivation (Family Influence)		0.85
My parents would disapprove if I chose a major other than engineering.[2]	0.75	
My parents want me to be an engineer.[1]	0.75	
2c. Motivation (Social Good)		0.70
Technology plays an important role in solving society's problems.[1]	0.54	
Engineers have contributed greatly to fixing problems in the world.[1]	0.54	
2d. Motivation (high School Teacher/Mentor Influence)		—
A high school teacher/advisor encouraged and/or inspired me to study engineering.		
One or more of my favorite high school teachers were math/science teachers.		
I had one or more high school math/science teachers who seemed genuinely excited about math/science.		
2e. Motivation (Mentor Influence)		0.65
A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.	0.48	
A non-university affiliated mentor has encouraged and/or inspired me to study engineering.	0.48	
3a. Confidence in Math and Science Skills		0.83
Science ability	0.74	
Math ability	0.73	
Ability to apply math and science principles in solving real world problems	0.61	
3b. Confidence in Professional and Interpersonal Skills		0.84
Leadership ability[5]	0.71	
Self-confidence (social)[4]	0.67	
Public speaking ability[5]	0.65	
Communication skills	0.62	
Ability to perform in teams	0.62	
Business ability	0.50	
3c. Confidence in Solving Open-ended Problems		0.69
I am skilled at solving problems that can have multiple solutions.	0.53	
Confidence: Critical thinking skills	0.52	
Creative thinking is one of my strengths.[1]	0.46	
4a. Perceived Importance of Math and Science Skills		0.79
Math ability	0.78	
Science ability	0.76	
Ability to apply math and science principles in solving real world problems	0.41	

APPENDIX (continued)

Construct and Item Content	Fall 05 Item-Total Correlation	Fall 05 Alpha
4b. Perceived Importance of Professional and Interpersonal Skills		0.79
Leadership ability [5]	0.70	
Public speaking ability [5]	0.65	
Self confidence (social) [4]	0.56	
Communication skills	0.55	
Ability to perform in teams	0.55	
Business ability	0.26	
5. Knowledge of the Engineering Profession		n/a
I am familiar with what a practicing engineer does.	n/a	
6a. Exposure to Project-Based Learning Methods (Individual Projects)		n/a
Since September, what percentage of your classes used the following teaching methods? Individual Projects:	n/a	
6b. Exposure to Project-Based Learning Methods (Team Projects)		n/a
Since September, what percentage of your classes used the following teaching methods? Team Projects:	n/a	
7. Frequency of Involvement in Extracurricular Activities		n/a
Some people desire to be involved in non-engineering activities on or off campus, such as hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc. How often are you involved in the kinds of activities described above?	n/a	
8. Perceived Importance of Involvement in Extracurricular Activities		n/a
Some people desire to be involved in non-engineering activities on or off campus, such as hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc. How important is it for you to be involved in these kinds of activities?	n/a	
9. Curriculum Overload		0.81
How stressed do you feel in your coursework right now?	0.74	
Thinking about your college experience this year, please comment on the following:		
Course load (amount of course material being covered)	0.68	
Course pace (the pace at which the course material is being covered)	0.63	
Balance between social and academic life	0.53	
How well are you meeting the workload demands of your coursework?	0.54	
10. Financial Difficulties		n/a
Do you have any concerns about your ability to finance your college education?	n/a	
11a. Academic Disengagement (Liberal Arts Courses)		0.58
Skipped non-engineering related class [5]	0.41	
Turned in non-engineering related assignments late [5]	0.41	
Came late to non-engineering related class [5]	0.38	
Turned in non-engineering related assignments that did not reflect your best work [5]	0.29	
11b. Academic Disengagement (Engineering Related)		0.70
Skipped engineering related class [5]	0.54	
Turned in engineering related assignments late [5]	0.51	
Turned in engineering related assignments that did not reflect your best work [5]	0.48	
Came late to engineering related class [5]	0.41	

APPENDIX (continued)

Construct and Item Content	Fall 05 Item-Total Correlation	Fall 05 Alpha
11c . Academic Disengagement (Overall)		0.74
Turned in non-engineering related assignments late [5]	0.51	
Turned in engineering related assignments late [5]	0.51	
Turned in engineering related assignments that did not reflect your best work [5]	0.48	
Came late to engineering related class [5]	0.43	
Came late to non-engineering related class [5]	0.43	
Skipped engineering related class [5]	0.42	
Turned in non-engineering related assignments that did not reflect your best work [5]	0.40	
Skipped non-engineering related class [5]	0.36	
12. Frequency of Interaction with Instructors		0.69
TAs outside of class or office hours [4]	0.53	
Faculty outside of class or office hours [4]	0.42	
Faculty during class	0.41	
TAs during class	0.41	
TAs during office hours [4]	0.40	
Faculty during office hours [4]	0.39	
13a. Satisfaction with Instructors		0.84
Availability of teaching assistants	0.74	
Quality of instruction by teaching assistants [3]	0.71	
Quality of advising by teaching assistants	0.71	
Quality of advising by faculty	0.61	
Availability of faculty	0.58	
Quality of instruction by faculty [3]	0.49	
13b. Satisfaction with Academic Facilities		0.83
Computer facilities [4]	0.70	
Classrooms [4]	0.68	
Libraries [4]	0.66	
Laboratories	0.59	
13c. Overall Satisfaction with Collegiate Experience		n/a
Rate the overall quality of your collegiate experience so far	n/a	

[1] Borrowed from the Pittsburgh Freshman Engineering Attitudes survey
[2] Borrowed from the Pittsburgh Freshman Engineering Attitudes survey, and modified slightly
[3] Borrowed from the CIRP survey, and modified slightly
[4] Borrowed from the Your First College Year 2003 survey
[5] Borrowed from the Your First College Year 2003 survey, and modified slightly