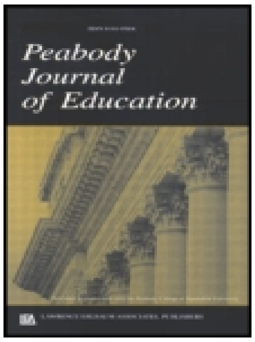

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Pathways to an Engineering Career

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Utilizing data from the 20-year record of the Longitudinal Study of American Youth (LSAY), this analysis uses a set of variables to predict employment in engineering for a national sample of adults aged 34 to 37. The LSAY is one of the longest longitudinal studies of the impact of secondary education and postsecondary education conducted in the United States. A structural equation model found that mathematics is a primary gateway to an engineering career, beginning with algebra track placement in Grades 7 and 8 and continuing through high school and college calculus courses. Home and family factors such as parent education and parent encouragement of science and mathematics during secondary school also enhanced the likelihood of a young adult becoming a professional engineer. In addition, young men were substantially more likely to become professional engineers than young women. Considering each of these factors, this article seeks to understand the varied pathways available to students interested in engineering careers.

For most of the last century, the United States and other industrial countries have viewed the number of young adults entering engineering careers as a major indicator of national standing and economic competitiveness (Wu, 2007). The National Academies' *Rising Above the Gathering Storm* (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005, 2010) argues for the education of more and better engineers, and the National Science Board's (NSB's; 2010) biennial *Science and Engineering Indicators* reports routinely include the number of new engineers as an indicator of U.S. achievement. Without seeking to resolve the issue of exactly how many engineers are needed, there is a broad consensus that sustaining a healthy flow of capable young adults into engineering careers is important for the health of the economy (Duderstadt, 2008; National Academy of Engineering, 2004, 2005; National Academy of Engineering & National Research Council, 2005; National Research Council, 1999a, 1999b, 2001). In this analysis, we first describe the current flow of young adults into professional engineering and then seek to identify the factors that are associated with successful entry into the field.

We are not the first investigators to examine this issue, and we acknowledge the large and useful literature that exists. A complete summary of prior work is beyond the scope of this

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analysis, but we acknowledge relevant work as we discuss current patterns and relevant variables related to this analysis.

This analysis is based on the cumulative record of the Longitudinal Study of American Youth (LSAY). A summary of the LSAY is provided by Miller and Kimmel (2012/this issue), and a complete description of the study and data is available at http://www.lsay.org.

THE FLOW OF YOUNG ADULTS INTO ENGINEERING

The educational and social science literature has documented the influence of parents on the formation of basic educational aspirations (Berger & Luckmann, 1966; Heppner & Scott, 2004; Whiston & Keller, 2004). Because of the pervasive influence of parents and home factors, there are substantial differences in initial reading readiness and skills among children when they reach formal schooling, and many of these differences persist throughout school and beyond (Oakes, 1985, 1990; Parsons, Adler, & Kaczala, 1982). In addition to language skills, parents also convey basic attitudes toward the value of education as a whole.

Parent encouragement of science and mathematics has been well documented in recent decades (see Miller & Kimmel, 2012/this issue). Anecdotes about parents buying LEGO sets for their infants in the hope that this early experience would stimulate an interest in science or engineering have their roots in real behaviors. Other parents use science museums, zoos, aquariums, and similar facilities to encourage their children to be interested in science and technology. The cumulative effect of this smörgasbörd of home and community resources supplements formal schooling, providing some children with a substantial advantage during their years of elementary and secondary schooling (NSB, 2010).

Is there evidence that these early events have any influence on the eventual selection and pursuit of a career in engineering? At the most basic level, the likelihood that a young adult will enter postsecondary study is closely related to the level of the parents' education (see Table 1). Nearly half of the children of parents without a high school diploma (or GED) never enroll in postsecondary education (PSE), compared to only 8% of the children of parents with a graduate or professional degree. Young adults who do not seek a baccalaureate will not become professional engineers.

Although the career preferences of high school students often change in college, we find it useful to look at the expected college major of high school students as one of the first steps toward a career in engineering. High school intentions are important because they may inform many of the decisions that a student will make in regard to the selection of classes and the level of effort that he or she will expend on specific courses and on academic work generally. Subsequent analyses will show that some of the high school students who expressed a preference for a career in engineering may migrate into other science, technology, engineering, mathematics, and medicine (STEMM) fields or non-STEMM fields, but very few students who planned to major in a field other than engineering later migrated into the field (Cross, 2001; Duderstadt, 2008). With this pattern in mind, we look at some of the factors related to the intended college major of high school seniors.

Although the level of parent educational attainment is strongly related to entrance into PSE (Chen, 2009), it is only weakly related to the selection of an engineering major in college. Approximately 9% of the children of college graduates plan to major in engineering, compared

TABLE 1
Distribution of Student Plans to Major in Engineering in Grade 12

	Expected College Major				
	Engineering	Other STEMM	Non-STEMM	No PSE	*N*
All LSAY respondents	7%	15%	56%	22%	3,539
Student gender					
Female	3	17	61	19	1,737
Male	11	13	51	25	1,802
Parent education					
Less than HS	3	5	45	47	233
HS graduate	6	12	53	29	1,614
Some college	7	17	56	20	492
Baccalaureate	10	17	62	11	634
Graduate or professional	8	20	64	8	544
Parent college push					
0 (low)	1	3	37	59	278
1	5	10	49	36	500
2	7	15	59	19	1,377
3	11	18	60	11	999
4–5 (high)	11	30	55	4	227
Parent science-math push					
0 (low)	2	9	52	37	577
1	5	9	60	26	541
2	6	11	60	23	675
3	6	14	62	18	950
4–5 (high)	16	26	45	13	796
Algebra track					
No algebra course in HS	1	2	34	63	361
Algebra I in Grades 10–12	3	11	57	29	957
Algebra I in Grade 9	8	19	61	13	1,631
Algebra I in Grade 8	18	22	56	4	461
Race/Ethnicity					
Hispanic American	6	10	52	32	288
African American	11	17	44	28	309
Asian American	15	27	56	2	117
Native American	8	8	51	33	49
Other American	7	15	57	21	2,574

Note. STEMM = science, technology, engineering, mathematics, and medicine; PSE = postsecondary educational institutions; LSAY = Longitudinal Study of American Youth; HS = high school.

to 6% of parents without a baccalaureate (see Table 1). The LSAY data suggest that overt parent encouragement of college attendance and encouragement of science and mathematics are substantially more important factors. A measure of parent college push illustrates the power of parent encouragement. Compared to 11% of students whose parents strongly encouraged college attendance, only 1% of students who experienced low parent encouragement to attend college planned to enter a postsecondary program and major in engineering. Overt parental encouragement of science and mathematics was even more influential. Only 2% of students whose parents provided a low level of science and mathematics encouragement planned to major in engineering in college, compared to 16% of the children of parents who provided strong math and science encouragement. In subsequent multivariate analyses, we examine the role of each of these kinds of parental encouragement, but it is clear that the cumulative impact of these factors will be significant.

Elementary and secondary schools provide important instruction in and early exposure to science and mathematics. Schools vary, however, in the scope and quality of their instruction (NSB, 2010; Taningco, Mathew, & Pachon, 2008). The selection of a school reflects a mix of parent, community, and economic factors, but some parents overtly seek high-quality schools for their children within their economic and geographic limits.

Within the school context, the two most important decision points occur at the initial study of algebra and the completion of a calculus course during high school (Chen, 2009; Kelly, 2009; NSB, 2010). In the late 1980s, when LSAY participants were in school, approximately 14% of students took their first algebra course in Grade 8 and 47% started algebra in Grade 9. Another 28% would take an initial algebra course in Grades 10 or 11. The sorting of students into algebra tracks constitutes the primary form of high school tracking in the United States. Eighteen percent of high school seniors who started algebra in eighth grade planned to major in engineering in college, compared to 8% of students who took 1st-year algebra in Grade 9 (see Table 1).

There are substantial differences by race and ethnicity in plans for an engineering major in college (see Table 1). Hispanic American, African American, and Native American students are significantly less likely to enroll in PSE (Higher Education Research Institute, 2010; Leggon & Pearson, 2009; National Science Foundation, 2009a, 2009b; Nettles & Millett, 1999). The small sample sizes for these groups in the LSAY make more detailed comparison perilous. From other analyses, we know that a substantial portion of the race and ethnicity differences shown in Table 1 are accounted for by differences in parent education, home resources, and differential school experiences.

Although high school juniors and seniors hold sincere expectations about their future college plans, a substantial literature documents significant slippage between intentions and actual PSE enrollment (Higher Education Research Institute, 2010; Mau, 2003; NSB, 2010; National Science Foundation, 2009b). The transition from high school to college is difficult for a number of reasons, but it is a very important gateway on the path to an engineering career.

Using most of the same variables that we employed to look at intended college major, we turn to a brief examination of the factors associated with PSE in an engineering program. Five percent of all LSAY students enrolled[1] in an engineering program after high school, a small drop from the 7% of high school seniors who expressed an intention to enroll in an engineering program (see Table 2).

An examination of the linkage between intended college major and actual enrollment shows the amount of slippage between intentions and actual enrollments. Only 43% of high school seniors who indicated that they intended to major in engineering initially enrolled in an engineering program. About 22% enrolled in another STEMM program, and 34% enrolled in a non-STEMM major. At the same time, only 3% of students who initially expressed an intention to major in a nonengineering field subsequently enrolled in engineering. This asymmetrical relationship

[1]In most cases, the enrollment occurred the year following the completion of high school, but in some cases the student may have deferred initial enrollment for a variety of reasons, including military service. One of the advantages of a longitudinal study that spans a number of years is that we can examine the behavior of interest regardless of its timing.

TABLE 2
Student Enrollment in an Engineering Program

	PSE Enrollment				
	Engineering	Other STEMM	Non-STEMM	No PSE	*N*
All LSAY respondents	5%	20%	53%	22%	3,539
Student gender					
Female	2	21	58	19	1,737
Male	8	19	48	25	1,802
Parent education					
Less than HS	1	14	38	47	233
HS graduate	5	18	48	29	1,614
Some college	5	24	51	20	492
Baccalaureate	7	18	64	11	634
Graduate or professional	6	25	61	8	544
Parent college push					
0 (low)	1	12	29	58	278
1	3	14	47	36	500
2	5	21	55	19	1,377
3	8	23	58	11	999
4–5 (high)	6	27	62	5	227
Parent science-math push					
0 (low)	3	14	46	37	577
1	2	14	58	26	541
2	3	18	56	23	675
3	5	21	56	18	950
4–5 (high)	10	28	49	13	796
Algebra track					
No algebra course in HS	0	10	27	63	361
Algebra I in Grades 10–12	2	16	53	29	957
Algebra I in Grade 9	6	23	58	13	1,631
Algebra I in Grade 8	13	25	58	4	461
Intended college major in Grade 12					
Engineering	43	22	34	1	250
Other STEMM field	3	59	39	0	515
Non-STEMM field	3	17	80	0	1,989
Did not enter PSE	0	0	0	100	785

Note. PSE = postsecondary educational institutions; STEMM = science, technology, engineering, mathematics, and medicine; LSAY = Longitudinal Study of American Youth; HS = high school.

reflects the high mathematics requirement associated with admission to an engineering program; prospective engineering students may decide to use their math skills in other fields, but students without advanced math skills cannot major in engineering without substantial additional work (see Chen, 2009).

Most parental, family, and school factors associated with the intention to major in engineering were also associated with actual college enrollment. The level of parent education was largely unrelated to enrollment in an engineering program, but the level of parent college push was related to enrollment in an engineering program. The level of parent encouragement of science and mathematics had an even stronger correlation with enrollment in an engineering program.

And, for the reasons discussed earlier, algebra track placement was very strongly related to enrollment in an engineering program (see Table 2).

The bivariate relationships shown in Tables 1 and 2 provide a general sense of the structure of a student's precollege life, and they suggest some ways in which these factors influence the selection of an initial career path. The examination of each of these factors in separate tables is interesting, but these factors occur simultaneously in the life of a student. It is necessary to estimate the relative influence of precollege factors seeking to analyze college and young adult experiences that may influence completion of an engineering degree and entrance into an engineering career. Following the logic outlined by Miller and Kimmel (2012/this issue), this analysis utilizes a structural equation model (SEM) to predict initial enrollment in an engineering program.

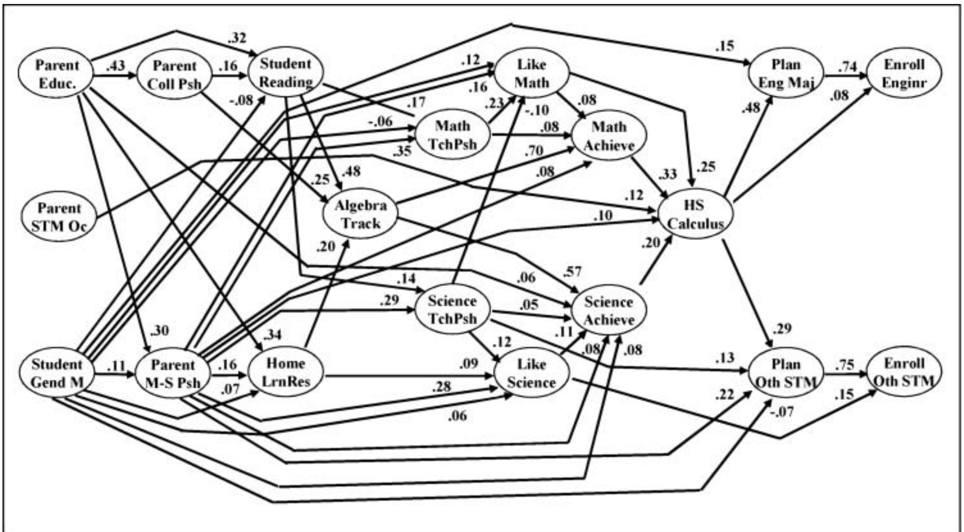
A PATH MODEL TO PREDICT INITIAL ENROLLMENT IN AN ENGINEERING PROGRAM

As discussed in the article by Miller and Kimmel, a structural equation path model helps us estimate the relative influence of each factor in models that include several factors. Miller and Kimmel's article provides a clear breakdown of the logic behind a SEM, but in general terms a SEM is a is a set of regression equations that predict each variable in the model and take advantage of our knowledge about the chronological or logical order of the variables. Look to Miller and Kimmel's article for a further breakdown of this method.

To understand the relative impact of selected variables on enrollment in an engineering program, we constructed a relatively simple path model (see Figure 1). Because influence and causation flow from left to right in a path model, the variables on the left side of the model are presumed to precede variables to their right either chronologically or logically. A detailed description of the construction of the major independent variables was provided in Miller and Kimmel (2012/this issue) and need not be repeated. The model was estimated using LISREL 9.0 (Hayduk, 1987; Jöreskog & Sörbom, 1993).

The results show that there is a relationship (represented by an arrow and called a path) from parent education to parent science-math push, with a path coefficient[2] of 0.30 (see Figure 1). This path and coefficient indicate that parents with higher levels of education were more likely to encourage their child to do well in science and mathematics during that child's high school years than parents with lower levels of education. The path from gender to parent science and math push (0.11) means that LSAY parents provided slightly more encouragement to their sons to study science and mathematics than they provided for their daughters. This finding holds constant the level of parent education and parent employment in a STEMM field (Hayduk, 1987). While holding constant parent education and student gender, we can see the absence of a path from parent employment in a STEMM field to parent science and math push. This indicates that parents who work in a STEMM field did not provide significantly more encouragement to their child to study science and mathematics than parents not employed in a STEMM job. These socialization behaviors are consistent with earlier studies by Parsons, Ruble, Hodges, and Small (1976).

[2]All of the paths shown in the model are significant at the .05 level or better.



Variables in Model		Engineering	Other STEMM
Gender	Student gender (male)	.13(.02)	.00(.00)
Home and family	Parent education	.09(.01)	.13(.02)
	Parent employment in a STEMM field	.05(.02)	.02(.01)
	Parent college push during high school	.05(.01)	.03(.01)
	Parent math-science push during high school	.10(.02)	.29(.03)
	Home science learning resources	.03(.01)	.03(.01)
	Student reading ability in high school	.08(.01)	.05(.01)
Secondary schooling	Student algebra track middle and high school	.15(.02)	.07(.01)
	Science teacher encouragement HS	.00(.00)	.11(.02)
	Mathematics teacher encouragement HS	.04(.01)	.02(.00)
	Student liked science as a subject in HS	.01(.00)	.16(.05)
	Student liked mathematics as a subject in HS	.12(.02)	.06(.01)
	Student science achievement score, grade 12	.09(.02)	.04(.01)
	Student math achievement score, grade 12	.14(.02)	.07(.01)
	Student completed calculus course in HS	.43(.04)	.21(.04)
	Student planned to major in engineering in coll.	.74(.10)	.00(.00)
	Student planned to major in other STEMM in coll.	.00(.00)	.75(.05)
	R^2 =	.60	.62

Fit statistics: Degrees of freedom = 111; Chi squares = 2142.4 (p = .00); Root Mean Square Error of Approximation (RMSEA) = .041; 90% confidence interval $_{(RMSEA)}$ = .038; .044; N = 3,062

FIGURE 1 A path model to predict enrollment in an engineering program.

In this analysis of precollege factors, we examined the full LSAY participant population using 3,062 young adults[3] who had data for each of the independent variables and the two outcome variables in the model. We included all of the students in this analysis in order to obtain accurate estimates of the influence of family and school factors. When we turn to an analysis of factors that occurred during PSE, we include only those students who enrolled in some form of PSE to obtain a more accurate estimate of college and other postsecondary effects.

The path model in Figure 1 demonstrates that a complex combination of factors contribute to each individual's decision to enroll in a postsecondary engineering program. Our analytic task is to identify the factors that cause some LSAY students to enroll in an engineering program and to estimate the relative strength of each of those factors.

An examination of the numerous paths in Figure 1 would reveal many interesting insights into the interaction of the variables included in this analysis, but one of the advantages of using SEM is that it provides accurate summary measures of the *total effect* of each of the variables in the analysis. Some variables in this model have a combination of positive and negative effects, and the total effect is the net effect of the variable on our outcome variable—enrolling in an engineering program. For example, the data in Figure 1 show that the parents of LSAY students provided both more encouragement and more home learning resources for their sons than their daughters. High schools girls, however, tended to have higher reading scores than high school boys, which provided numerous advantages in school programs. When these advantages and disadvantages were combined, and controlling for the other factors that occurred during the secondary school years, the results showed that male students were more likely to enroll in engineering programs than female students, with a total effect of 0.13 (see Figure 1). In contrast, there is no gender difference in terms of the likelihood of male and female students enrolling in other PSE STEMM programs. This result is consistent with our observations of the enrollment data from Table 2, but it provides a more accurate estimate of the net effect of gender on engineering enrollment when we hold constant a wide range of other factors. For clarity and simplicity, this initial analysis focuses on the total effects found in this precollege model.

In our examination of the total effects of the variables included in our model, the importance of early algebra and a strong math program (including the completion of a calculus course in high school) appeared as key factors in predicting enrollment in engineering (see Figure 1). Early enrollment in algebra provided an initial advantage (total effect = 0.15), which was linked with a positive student attitude toward mathematics (0.12) and higher levels of achievement in subsequent mathematics courses (0.14). The result of this sequence is the completion of a calculus course in high school, which had a total effect of 0.43 (see total effects table in Figure 1). These factors (in addition to parental encouragement) appeared to lead to a student's intention to enroll in engineering, and this intention may have influenced a wide array of other choices and activities during the high school years. The total effect of planning to enter engineering (0.74) illustrates the importance of early career decisions on subsequent enrollment decisions and behaviors.

We would like to note briefly some of the factors that did not predict enrollment in a PSE engineering program. Parent employment in a STEMM field was weakly related to enrollment in an engineering program (0.05), discounting the idea that the children of scientists and engineers follow their parents' choices in large numbers. The legendary influence of LEGO sets and other

[3]The cases included in this analysis are weighted to reflect the original student population in the study.

home science learning resources had minimal effect on enrollment (0.03). Similarly, encouragement from science or mathematics teachers appeared to have little impact on actual enrollment decisions. A positive attitude toward mathematics had a moderate influence on enrollment in an engineering program (0.12), but a student's interest in science did not (0.01). Student achievement in science (0.09) had less influence on engineering enrollment than success in high school mathematics.

The precollege model accounted for 60% of the total variance in enrollment in a PSE engineering program (see note in Figure 1). As demonstrated by the fit statistics, this is a good fitting model.

A PATH MODEL TO PREDICT THE COMPLETION OF A BACCALAUREATE IN ENGINEERING

The initial analysis examined factors associated with entrance into a PSE engineering program, which is an essential entry point on the path to employment as a professional engineer. The second step in that process is the completion of a baccalaureate degree in engineering. We thus seek to identify the major factors associated with completion of an engineering baccalaureate. We have expanded our initial model to include the number of college calculus courses and the number of college science courses completed during the undergraduate years. We also add two new outcome variables—the completion of an engineering baccalaureate and the completion of a baccalaureate in another STEMM field. Although our primary focus in this analysis is the pathways into professional engineering, comparative information about the pathways to other STEMM baccalaureate degrees is instructive.

For this examination of the factors related to the completion of a baccalaureate in engineering, we limited our population to those students who had enrolled in either a community college or a senior college. As observed in Tables 1 and 2, approximately 78% of LSAY participants had enrolled in a PSE institution. It would have been inappropriate to include students who had never entered PSE in an analysis of the impact of college calculus courses, for example.

Among the PSE population, young men were 7 times more likely to earn a baccalaureate in engineering than were young women, although young women who entered PSE were more likely to complete a baccalaureate than were young men (see Table 3). Students whose parents strongly encouraged college attendance were slightly more likely to complete an engineering baccalaureate than students whose parents provided lower levels of college encouragement. Parent encouragement of science and mathematics during the middle school and high school years was positively associated with the completion of an engineering baccalaureate. And student enrollment in eighth-grade algebra continued to be a major predictor for the completion of a baccalaureate in engineering.

At the university level, the number of calculus courses completed during college was strongly related to the completion of an engineering baccalaureate. The completion of one or more college calculus courses was strongly associated with all STEMM fields (Chen, 2009). This partly explains the importance of eighth-grade algebra and 12th-grade calculus during the secondary school years.

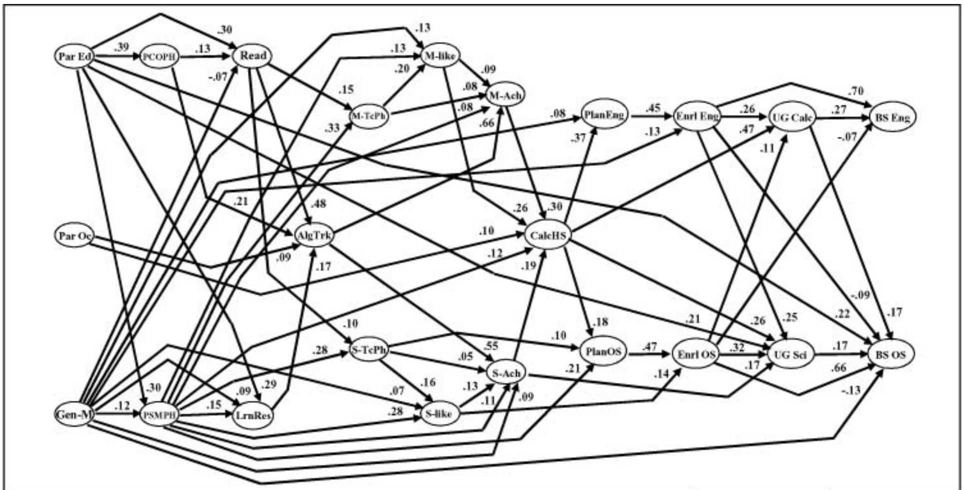
To assess the importance of both precollege and college factors on the completion of an engineering baccalaureate, we will utilize our extended path model (see Figure 2). We focus our analysis on the total effects of the variables in the model (see total effects table in Figure 2).

TABLE 3
Student Completion of a BS in Engineering

	Earned Baccalaureate in . . .				
	Engineering	Other STEMM	Non-STEMM	Did Not Complete	*N*
All LSAY respondents	4%	13%	39%	44%	2,752[a]
Student gender					
Female	1	15	42	42	1,403
Male	7	12	35	46	1,349
Parent education					
Less than HS	0	5	26	69	124
HS graduate	3	9	32	56	1,155
Some college	3	12	33	52	394
Baccalaureate	6	17	51	26	566
Graduate or professional	5	23	49	23	504
Parent college push					
0 (low)	2	4	21	73	115
1	1	6	28	65	322
2	3	12	38	47	1,116
3	6	16	47	31	889
4–5 (high)	4	26	47	23	214
Parent science-math push					
0 (low)	2	7	34	57	364
1	1	9	39	51	398
2	3	12	39	46	516
3	3	13	41	43	779
4–5 (high)	9	20	39	32	693
Algebra track					
No algebra course in HS	0	2	13	85	134
Algebra I in Grades 10–12	1	5	27	67	677
Algebra I in Grade 9	4	16	44	36	1,420
Algebra I in Grade 8	10	21	50	19	441
No. of college calculus courses completed					
None	1	8	37	54	1,848
1 or 2 courses	2	24	53	21	573
3 or more courses	33	29	29	9	249

Note. STEMM = science, technology, engineering, mathematics, and medicine; LSAY = Longitudinal Study of American Youth; HS = high school.
[a]This table includes only respondents who enrolled in postsecondary education at the community college or senior college level. $N = 2{,}752$.

When predicting the completion of an engineering baccalaureate, and holding constant the other factors in the model, the influence of gender remained strong, with a total effect of 0.15, indicating that men were more likely to complete an engineering baccalaureate than women. Women were slightly more likely to complete a baccalaureate in nonengineering STEMM fields (–0.08) than men when all other things were held equal. We return to this issue in our closing discussion.



Variables in Model		BS Engineering	BS Other STEMM
Gender	Student gender (male)	$.15_{(.02)}$	$-.08_{(.02)}$
Home and family	Parent education	$.05_{(.01)}$	$.32_{(.04)}$
	Parent employment in a STEMM field	$.03_{(.01)}$	$.02_{(.01)}$
	Parent college push during high school	$.02_{(.01)}$	$.02_{(.00)}$
	Parent math-science push during high school	$.07_{(.01)}$	$.16_{(.02)}$
	Home science learning resources	$.01_{(.00)}$	$.01_{(.00)}$
	Student reading ability in high school	$.04_{(.01)}$	$.04_{(.01)}$
Secondary schooling	Student algebra track middle and high school	$.08_{(.01)}$	$.06_{(.01)}$
	Science teacher encouragement HS	$.01_{(.00)}$	$.06_{(.01)}$
	Mathematics teacher encouragement HS	$.02_{(.00)}$	$.01_{(.00)}$
	Student liked science as a subject in HS	$.01_{(.00)}$	$.11_{(.03)}$
	Student liked mathematics as a subject in HS	$.07_{(.01)}$	$.04_{(.01)}$
	Student science achievement score, grade 12	$.05_{(.01)}$	$.06_{(.01)}$
	Student math achievement score, grade 12	$.08_{(.01)}$	$.05_{(.01)}$
	Student completed calculus course in HS	$.26_{(.03)}$	$.16_{(.03)}$
	Student planned to major in engineering in coll.	$.34_{(.04)}$	$.04_{(.01)}$
	Student planned to major in other STEMM in coll.	$.01_{(.00)}$	$.35_{(.03)}$
Undergraduate Experience	Student initial enrollment in engineering program	$.77_{(.06)}$	$.09_{(.01)}$
	Student initial enrollment in other STEMM prog.	$.03_{(.01)}$	$.73_{(.04)}$
	Number of student college calculus courses	$.27_{(.04)}$	$.17_{(.03)}$
	Number of student college science courses	$.00_{(.00)}$	$.17_{(.04)}$
	R^2 =	.68	.71

Fit statistics: Degrees of freedom = 181; Chi squares = 3886.9 (p = .00); Root Mean Square Error of Approximation (RMSEA) = .048; 90% confidence interval $_{(RMSEA)}$ = .045; .051; N = 2,367

FIGURE 2 A model to predict completion of a BS in engineering.

Several family and home variables continued to exercise an influence on the completion of an engineering baccalaureate, including parent education (0.05) and parent math-science push (0.07). Algebra track assignment had a positive effect (0.08) on the completion of an engineering baccalaureate as did high school achievement in science (0.05) and mathematics (0.08), but the completion of a high school calculus course remained the strongest precollege predictor of the successful completion of an engineering baccalaureate (0.26; see Figure 1). The strength of these factors declined over the years after high school, but they were never completely replaced by post–high school experiences.

Reflecting its gatekeeper role, initial enrollment in a PSE engineering program had a strong postsecondary influence, with a total effect of 0.77. The number of college calculus courses positively related to the completion of an engineering baccalaureate (0.27), but the number of college science courses proved unrelated to the completion of an engineering baccalaureate. In broad terms, these results point to the structured nature of undergraduate engineering education. The completion of specific requirements is essential to a degree and position in the engineering field.

This postsecondary model accounted for 68% of the total covariance in the completion of a baccalaureate in engineering. The other fit statistics suggest that this is a good fitting model.

ENTRY INTO THE ENGINEERING PROFESSION

Having examined initial enrollment in an engineering program and subsequent completion of a baccalaureate in professional engineering, we turn to an examination of actual employment and work in the field. Most professional engineers enter the workforce with a baccalaureate degree and continue to work without additional graduate or postgraduate degrees. In addition, some individuals with an engineering baccalaureate enter professions and occupations other than engineering.

Examining the LSAY cohorts, 58% of engineering baccalaureates have entered the profession and are working as engineers. An additional 12% of engineering baccalaureates have entered other STEMM occupations (medicine or health are most common). Approximately 70% of engineering baccalaureates are employed in the STEMM professional workforce currently. Approximately 20% of engineering graduates report that they have found employment in businesses and other occupations that are not directly involved in engineering, although their engineering education may aid to them in their current work. The remaining 10% have moved into other fields or are out of the workforce for various reasons.

DISCUSSION

This analysis demonstrates that the pathways to an engineering career are long and complex, as Super (1957, 1980; Super & Bowlsbey, 1979) and Krumboltz (1976) suggested they would be. To become a professional engineer, a student must successfully negotiate a series of educational gates over a period of years while sustaining interest and focus. Too often, cross-sectional studies have focused on short-term influences, but this longitudinal record indicates that many factors have early roots and long-term impact (Paa & McWhirter, 2000; Turner & Lapan, 2002).

Secondary school tracking is an early factor that significantly influences a number of outcomes. Although tracking begins in elementary school, the best single indicator of track placement relative to engineering is the year in which a student first takes algebra. Students who begin algebra in Grade 7 or 8 have a substantial advantage throughout secondary school. In this model, algebra track placement was the strongest predictor of both mathematics achievement and science achievement. Students who did not begin algebra until Grade 9 were significantly less likely to complete a calculus course in high school and, in turn, less likely to enter or complete a baccalaureate in engineering. Unfortunately, this critical decision point continues to be largely invisible to many students and parents. Despite the strong recommendation of the National Council of Teachers of Mathematics more than 20 years ago that a majority of students should begin algebra in Grade 7 or 8, there has been limited progress in this area.

The main message of this model is that mathematics is the gateway to an engineering career. The completion of a calculus course in high school and the number of college calculus courses taken were two of the strongest predictors of the completion of an engineering baccalaureate degree. Math, then, remains the definitive gateway into engineering education and, ultimately, into the engineering profession.

This model also points to the importance of degree completion at the baccalaureate level. Nearly one third of students who enter a PSE engineering program fail to complete a baccalaureate in any field. We recognize that students will change their thinking about career choices during their college years and think that this is generally a healthy process that enhances the fit between education and one's life work, but we are disappointed with the high level of noncompletion at the PSE level. In a flat and competitive world, dropping out of PSE has serious economic consequences that are often difficult to overcome in later years.

This model indicates that a student's interest in an engineering career during high school is an important factor in both initial enrollment and completion of an engineering baccalaureate. Our description of the variable—an intention to major in engineering in college—may understate the importance of the attitudes and behaviors implied by this variable. Student career plans during high school are important in that they inform the student and the parents about the kind of courses and education that will be necessary for the attainment of this goal. Most students and school counselors recognize that mathematics—and, specifically, calculus—is necessary for success in engineering. The earlier that a student adopts a career target, the more choices he or she can make about courses in school and supplemental activities out of school. Students who begin algebra in Grade 10 or later have virtually no chance of obtaining entry into a baccalaureate engineering program without extensive remedial work in mathematics. Although a late decision to seek entrance into an engineering program does impacts other areas' curriculum, the impact on mathematics course selection can be catastrophic.

Finally, this model points to the continuing importance of gender in understanding successful entrance into an engineering career, as it identifies several points at which gender is an important influence, beginning with parental attitudes and encouragement. High school boys report slightly more parental encouragement to study science and mathematics than girls (0.11), but high school girls—perhaps with parental encouragement and attention—score higher on reading tests. Female students are also more likely to earn a baccalaureate than male students. Despite these findings, and considering all of the positive and negative pathways, male LSAY participants were significantly more likely to both enter a postsecondary engineering program and earn an engineering baccalaureate than were female participants (0.13). The continuing gender disparity in the professional engineering workforce is and should be a subject of national concern.

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