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The Role of High School Math and Science Course Access in Student College Engineering Major Choice and Degree Attainment

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I. Introduction

Previous research has documented numerous factors that impede the progress of women and underrepresented minorities in engineering fields, which can be broadly categorized into six factors: "classroom and academic climate, grades and conceptual understanding, self-efficacy and self-confidence, high school preparation, interest and career goals, and race and gender" (Geisinger and Raman, 2013). While high school preparation is a critical determinant in student success, many of the connections between high school characteristics and college outcomes have not been thoroughly studied. This study helps fill this important knowledge gap by examining how high school math and science course taking, as well as access to high school math and science courses, explain engineering major choice and degree attainment in college.

To identify the connection between high school math and science courses and college engineering major choice and degree completion, we apply both descriptive and regression analyses. We use comprehensive administrative data from the Missouri Department of Elementary and Secondary Education (DESE). The sample includes all public high schools (grades 10-12) in Missouri between 1996 and 2009. Data include student-level demographic information and academic transcripts, as well as high school-level characteristics (e.g., proportion of students on free and reduced lunch, number of math and science offered, and level of urbanicity).

The number of math and sciences credits offered at high schools may determine the level of preparation prospective engineering students in college have and should also be taken into account when designing first-year engineering courses. High school characteristics help shape the opportunities and experiences of students, and should be considered in college recruitment strategies and in the evaluation of individual college applications. Therefore, our findings have important implications for understanding how to prepare high school students to pursue college engineering majors, as well as for college engineering programs to consider how high school academic records should be considered in terms of admissions policies.

II. Background

A. Diversity in Engineering Education and the Workforce

Participation in engineering among underrepresented minorities, including women, black, Hispanic, and Native American, has remained stagnant or grown relatively slowly. Previous studies have documented numerous factors that impede the progress of women and underrepresented minorities in engineering, including unsupportive academic environments and culture; lack of role models; limited student-faculty interactions; and individual differences in levels of self-efficacy, sense of belonging, and engineering identity (Adelman, 1998; Blickenstaff, 2005; Johnson & Sheppard, 2004; Lent, et al., 2008; Marra et al., 2012; Ong et al., 2011; Seymour & Hewitt, 1997; Tonso, 1999 & 2006; Tsui, 2010; Geisenger & Raman, 2013). Because most students apply directly to engineering colleges and programs during high school, major choice for engineering students occurs relatively earlier compared to other college students. Therefore, it may be that high school level factors may be one of the more critical factors influencing participation in engineering.

B. High School Level Factors

Prior research indicates that taking courses in math and science during high school is positively associated with whether a student will select a STEM field in college (e.g., Tyson et al., 2007; Tyson, 2011). Other pre-college factors, including exposure to math and science courses, math achievement, and levels of self-efficacy, contribute to students' decision-making (Blickenstaff, 2005; Maple & Stage, 1991; Seymour & Hewitt, 1997; Wang, 2013). Academic achievement in high school is also critical to a student's probability of being admitted into a college engineering program. A study by Holloway et al. (2014) documented gender bias in admissions policies and processes that privilege the admission of men into engineering programs. They found that admissions selection criteria placed more emphasis on Scholastic Aptitude Test (SAT) scores and high school rank, even though taking more math and science courses in high school was a better predictor of persistence in engineering among women. Based on their analysis, they recommended a "reduced emphasis on standardized math scores, and stronger emphasis on SAT verbal and written scores, as well as on the number of semesters of mathematics, science, and English taken in high school" (p. 291). A lesson from their study is that it is critical to identify the availability and exposure to STEM courses during high school because it may have implications for not only interest in engineering, but also the probability of being admitted to certain engineering programs.

C. Connecting High School Level Factors to College Major Choice and Persistence

There has been extensive work on the factors that influence student major choice; these factors include parental influence, career prospects, educational interests, academic preparation, self-identity, role models, chilly climate, social status, financial aid, and cognitive skills. (Adelman, 1998; Arcidiacono & Koedel, 2014; Blickenstaff, 2005; Johnson & Sheppard, 2004; Lent, et al., 2008; Marra et al., 2012; Ong et al., 2011; Seymour & Hewitt, 1997; Tonso, 1999, 2006; Tsui, 2010). While previous research has examined how social influences from peers, teachers, and parents influence major choice in engineering disciplines (Ngambeki, 2012; Carnasciali, et al., 2013), the connections between high school level characteristics and college success in engineering have not been comprehensively studied.

Recent work by Legewie and Diprete (2014), Wang (2013), and Engberg and Wolniak (2013) attempt to understand the relationships between high school math and science course taking and college major choice. Wang (2013) analyzed the nationally representative Education Longitudinal Study (ELS) 2002 data and found that the level of math achievement critical, and that exposure to STEM courses in high school increases interest in STEM disciplines at the college level. Engberg and Wolniak (2013), also using ELS 2002, found that course-taking behavior during high school significantly predicts STEM major selection in college. Further, these authors showed that differences in high school educational environments, e.g., teaching methods that utilize real-world applications of science and math concepts, are positively related to STEM major choice.

Using the National Education Longitudinal Study (NELS), Legewie and DiPrete (2014) similarly found that high school context matters—high school STEM curriculum and the level of gender segregation of extracurricular activities is associated with the diversification of college STEM fields. Yet, all of these studies aggregate STEM disciplines, leaving student selection into *engineering* majors still relatively ambiguous. Unlike science, technology, and mathematics, engineering curricula have not been widely adopted in K-12 schools; this means that students have less exposure to the field during secondary education. Since K-12 exposure to engineering is so different, it is reasonable to assume that selection into engineering may be associated with different factors than selection into science, technology, or mathematics.

Arcidiacono and Koedel (2014) used Missouri administrative higher education data to decompose the racial graduation gap differences among black and white students across public four-year colleges in the state. They found that pre-college skills are the largest contributor to disparities in college degree attainment, and that college choice and high school quality were particularly relevant to the college success of black women. These findings are consistent with the important role we hypothesize that high schools play in determining college outcomes (and pre-college preparation more generally). However, Arcidiacono and Koedel focused on college graduation more broadly, not engineering degree attainment specifically. Our research will therefore add clarity to the literature in engineering education by focusing the analysis specifically on engineering degrees.

III. Data

The longitudinal data come from the Missouri Department of Higher Education administrative data. The dataset includes all full-time, first-enrollment students who attended a Missouri public high school and matriculated into one of Missouri's 13 public, four-year institutions between 1996 and 2009. For each individual, we are able to track at least six years of their postsecondary experience through transcripts, such that we are able to observe their entry in a public college and their exit from the college system up to 6 years after their entry. We supplement this dataset with additional administrative data from Missouri High School system, as well as with information from the Census Bureau and the National Center for Educational Statistics (NCES) Common Core. Therefore, the resulting data set provides a comprehensive look at the experiences of students in Missouri from high school through postsecondary education. The resulting dataset includes approximately 156,000 individual students. We present summary statistics in Table 1. Approximately 55% of the sample is female, 9% black, 2% Hispanic, and 2% Asian.

Table 1: Sample Summary Statistics

	Mean	SD
Students		
Male	45%	
Female	55%	
White	84%	
Black	9%	
Hispanic	2%	
Asian	2%	
Other race/ethnicity	4%	
Number of Students	156009	
High Schools		
Graduates	112	121
Enrollment	550	533
Number of High Schools	521	

The count of high schools includes public high schools only, and all numbers are annual, weighted by high school-year. The number of high schools that send students to the public 4-year system varies by year.

IV. Methods

We examine the relationship between student high school math and science course taking and subsequent college engineering major choice and degree attainment using both descriptive and regression analyses. We describe the percentage of the Missouri student population who pursue college engineering majors and who attain engineering bachelor's degrees by gender and race/ethnicity. To illustrate potential differences in high school math and science courses taken, we calculate the average number of courses completed among engineering and non-engineering students by gender and race/ethnicity. We also demonstrate the average number of high school math and science courses offered between those who complete college engineering majors and non-engineering majors by student demographic group.

We estimate the likelihood of engineering major choice and engineering degree attainment as a function of high school math and science course taking and course access, as well as race/ethnicity, gender, and other student and high school level characteristics, using the following equation:

$$Y_{ijh} = \alpha_0 + \alpha_1 C_{ih} + \alpha_2 R_i + \alpha_3 F_i + \alpha_4 X_{1i} + \alpha_5 X_{2jh} + d_t + \epsilon_{ijh}. \tag{1}$$

where Y is equal to one if student *i* from high school *j* majored or graduated in engineering in year *h*, and zero otherwise. The initial major choice outcome is defined as whether the student's first major is engineering, whereas the outcome degree is defined as whether the student graduated with an engineering degree. Consistent with previous studies, the key variable of interest, *C,* is defined as the number of math and science courses taken. We also estimate separate models using a second definition where *C* as the number of math and science courses *available* during the period of the student's high school attendance. Our preferred specifications use course availability (course access) as the key independent variable because availability is not influenced by students' endogenous course-taking behaviors conditional on course offerings.

R is a vector of race/ethnicity indicators, black, Hispanic, Asian, or other race, with white as the omitted group. *F* is an indicator for being female, with male as the omitted group. The X_1-vector controls for student characteristics, including student class rank, ACT math and reading scores, and year of high school graduation. The X_2-vector controls for time varying high school characteristics, including level of urbanicity (urban, suburban, or rural), enrollment, percent of the student body that identifies as a minority race/ethnicity, and percent of the student body which is free or reduced price lunch eligible. d_t is a year fixed effect, α_0 is the estimated intercept, and ϵ is an error term. Standard errors are clustered at the high school level.

To account for unobservable high school factors that may be related to the availability of math and science courses and student college degree attainment, we also estimate an additional model using equation 1 with a high school fixed effect, d_j. This model is shown in equation (2).

$$Y_{ijh} = \beta_0 + \beta_1 C_{ih} + \beta_2 R_i + \beta_3 F_i + \beta_4 X_{1i} + \beta_5 X_{2jh} + d_t + d_j + e_{ijh}. \tag{2}$$

All of the covariates are defined as in equation 1 above, except level of urbanicity (urban, suburban, or rural) is omitted since it is a time invariant high school factor.

V. Results

A. Engineering Major Choice and Degree Attainment

Table 2 summarizes engineering major choice, engineering degree attainment, and overall graduation rates. Overall, 11% of students initially major in engineering and 6% of entering students are awarded engineering degrees. In column 1, considering all students who matriculated in a 4-year institution in Missouri, the percentage of students across race/ethnicity groups pursue engineering at relatively similar rates: 10% of black, 11% of white, 12% of Hispanic, and 13% of Asian students major in engineering. However, when looking at engineering degree attainment in column 2, there appears to be disparities by race/ethnicity. A greater proportion of Asian students initially major and graduate in engineering. Meanwhile, only 3% of black and 5% of Hispanic students who earn an engineering degree. In terms of the overall graduation rate, regardless of major, white and Asian students have a six-year college graduation rate of 62% and 63%, respectively. White students are almost two times as likely to graduate with a degree as black students (37%).

Table 2: Engineering Major Choice, Engineering Degree Attainment, and College Graduation Rates

	% of Entering Students with Engineering		
	Initial Major	Degree	Graduation Rate (%)
	(1)	(2)	(3)
All Students	11	6	59
By Gender			
Male	21	12	56
Female	3	2	62
By Race/ethnicity			
White	11	6	62
Black	10	3	37
Hispanic	12	5	54
Asian	13	8	63
Other Race/Ethnicity	12	7	56

Notes: All numbers in the table are in percentage points. Degree reflects degree acquisition in six years. Graduation rate is overall graduation rate, regardless of major, for students in each subgroup.

A greater proportion of male students (21%) major in engineering compared to female students (3%). Column 2 suggests that even though men enter engineering at higher rates than women, they may also have relatively lower graduation rates in engineering. Only 12% of men and 2% of women who graduate with bachelor's degrees do so in engineering. The graduation rate for all majors in column 3 lends some support to this. Men's graduation rate of 56% is lower than women's graduation rate of 62%. These reported graduation rates, however, are for all students regardless of major. We examine more closely these trends in engineering major choice and degree attainment in section B below. Building on previous literature that found a relationship between high school course taking and college major choice, we present the average number of math and science courses available and taken between engineering majors and non-majors by gender and race/ethnicity. We follow with an examination of the influence of math and science course taking and access in high school on college engineering major choice and degree attainment while controlling for race/ethnicity in the regression analyses.

B. Math and Science Course Taking in High School and College Engineering Major Choice and Degree Attainment

The connection between engineering degree attainment and (1) high school math and science courses taken, and (2) high school math and science course availability are summarized in Table 3 by student gender and race/ethnicity. Across all students, those who graduate in engineering take on average more math and science courses, as well as attend high schools that offer more math and science courses, compared to non-engineering majors. For example, engineering degree recipients take an average of 8.1 high school math and science courses compared to non-engineering degree recipients who take an average of 7.4 high school math and science courses. The average number of math and science courses (90.4) offered at high schools that engineering degree recipients attended is generally similar to the average number of math and science courses (88.1) offered at high schools that non-engineering degree recipients attended.

We also examine high school math and science course-taking and availability/access patterns by student gender and race/ethnicity. Within each demographic group, similar patterns hold where engineering degree recipients take on average more high school math and science courses than non-engineering degree recipients. Engineering degree recipients within each demographic group also attended high schools where relatively more math and science courses are available, with the exception of Hispanic students. Hispanic students with engineering degrees attended high schools that offered fewer math and science courses than those attended by Hispanic students with non-engineering degrees.

There are some disparities in course taking behavior when comparing across demographic groups. Female engineering degree recipients (8.2) take about the same number of math and science courses as male students (8.0). However, Asian students take more math and science courses in high school compared to their peers. Hispanic and black students take slightly fewer math and science courses than white students. In terms of course availability, compared to their peers, black and Asian students tend to attend high schools that offer more math and science courses compared to their counterparts, but this could be a function of the relatively larger high schools these students attend.

Table 3: Math and Science Courses Taken and Course Availability in High School

	Courses Taken		Course Availability	
	Engineering Degrees	Non-Engineering	Engineering Degrees	Non-Engineering
	(1)	(2)	(3)	(4)
All Students	8.1	7.4	90.4	88.1
By Gender				
Male	8.0	7.5	90.3	88.7
Female	8.2	7.4	91.0	87.7

By Race/ethnicity				
White	8.1	7.4	88.7	86.4
Black	7.3	7.0	107.8	100.7
Hispanic	7.9	7.4	93.1	100.3
Asian	8.9	8.6	109.0	105.3

C. Influence of High School Math and Science Course Availability and Student Course Taking on College Engineering Major Choice and Degree Attainment

We present results from our models of the likelihood of engineering major choice and degree attainment in Tables 4 and 5. Consistent with previous research, we find that students who take more math and science courses in high school are more likely to initially major in engineering (Table 4, columns 1 and 2) and to attain an engineering degree (columns 4 and 5). The patterns weaken significantly when we focus on course availability/access rather than courses taken (Table 5), and are not present using either measure in our preferred specifications that include high school fixed effects to account for potential endogeneity in course-offerings associated with fixed high-school characteristics (columns 3 and 6 in Tables 4 and 5).

Table 4: Estimates of Engineering Major and Degree, Courses Taken

	Initial Major			Degree		
	(1)	(2)	(3)	(4)	(5)	(6)
Courses Taken	0.029	0.027	0.002	0.022	0.020	-0.002
	(0.002)**	(0.002)**	(0.001)	(0.001)**	(0.001)**	(0.001)
Individual & HS controls		X	X		X	X
HS FE			X			X

Table 5: Estimates of Engineering Major and Degree, Courses Available

	Initial Major			Degree		
	(1)	(2)	(3)	(4)	(5)	(6)
Courses Available	0.006	0.003	0.005	0.006	-0.001	-0.002
	(0.002)**	(0.004)	(0.004)	(0.001)**	(0.003)	(0.003)
Individual & HS controls		X	X		X	X
HS FE			X			X

Notes to Tables 4 and 5: Each coefficient is from a separate regression. All models control for high school graduation year and calendar year. Student controls are gender, race/ethnicity, ACT math and reading scores, and high school class rank. High school controls include urbanicity (urban, suburban, or rural; this factor drops out with the inclusion of HS fixed effects), enrollment, percent of the student body that identifies as a minority race/ethnicity, and percent of the student body which is free or reduced price lunch eligible. Standard errors clustered by high school included in parentheses. ** $p<0.01$, * $p<0.05$.

VI. Discussion and Future Work

Similar to prior research, we show that students who have taken on average more math and sciences courses are more likely to pursue engineering majors and to complete the degree, and that there are differences in course taking by race/ethnicity. Similarly, students who attended high schools that offer more math and science courses are more likely to be engineering degree recipients rather than non-engineering degree recipients. High school math and science course access also varies by race/ethnicity in this context.

An important contribution of our work is that when we move from descriptive analyses to estimate fixed effects regression models (using equation 2) that more robustly address issues associated with endogeneity, the observed relationships between high school math and science courses on engineering major choice and degree attainment disappear. Our findings indicate that the volume of high school math and science course availability, all else held constant, does not have a causal relationship with college-level engineering major choice or degree attainment. Our findings highlight the complexities surrounding the influence of high school level factors on the academic college trajectories of students. They suggest critical areas for further exploration to more robustly identify the effects of high school math and science courses toward facilitating institutional programmatic and policy decisions.

We plan to continue to examine the contributions of high school level factors toward student engineering major choice and degree attainment. Specifically, our measure of access to math and science courses used in this analysis do not yet take into account the rigor/level of courses available and this may be a significant factor in determining subsequent engineering major choice and degree attainment. This line of analysis will also delve deeper into the unique contributions of course type (for example, math versus science) in determining major choice, as well as preparation for specific engineering disciplines (for example, choice of college computer science or mechanical engineering majors). We also plan to estimate models that take into account normalized measures of student course taking behavior as a function of high school course availability to identify how taking more or fewer courses relative to peers may account for college academic outcomes. In regard to increasing the participation of women and underrepresented minority students in engineering, our descriptive analyses highlight important areas for further exploration. We plan to examine further the connection between high school course availability and the disparities in engineering participation by gender and race/ethnicity.

VII. Conclusion and Implications

While we were able to demonstrate similar descriptive trends and regression findings linking high school math and science course-taking to engineering major choice and degree attainment as in previous studies, we also show that more robust empirical methods do not lead to similar results. Instead, we do not find evidence that volume of high school math and science courses offered is related to engineering major choice or engineering degree completion, all else held constant. Our findings highlight the importance of methodological choice in the study of student academic pathways and outcomes, as well as the complexities surrounding the role of high school level factors in student academic trajectories. Additionally, our descriptive trends demonstrate disparities in high school math and science course taking and course availability by race/ethnicity, which require further examination. Taken together, our research findings leave open the possibility that high school level factors are an important source of the differential participation in engineering by gender and race/ethnicity, but further work is needed to understand mechanisms.

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