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Does Teaching Matter? Factors that Influence High School Students' Decisions Whether to Pursue College STEM Majors

Dr. Gary Lichtenstein, Quality Evaluation Designs

Gary Lichtenstein, Ed.D., is principal of Quality Evaluation Designs, a firm specializing in research and evaluation for K-12 schools, universities, and government and non-profit organizations nationwide. He has researched STEM pathways of K-12 students, undergraduates, and early career professionals. For correspondence about this paper, email: gary@QualityEvaluationDesigns.com,

Dr. Martin L Tombari, University of Texas, Austin

Marty Tombari is a senior lecturer in the Department of Educational Psychology at the University of Texas-Austin. He teaches basic statistics courses to undergraduates and measurement courses to graduate students in the Master's and Doctoral Programs.

Dr. Sheri D. Sheppard, Stanford University

Sheri D. Sheppard, Ph.D., P.E., is professor of Mechanical Engineering at Stanford University. Besides teaching both undergraduate and graduate design and education related classes at Stanford University, she conducts research on engineering education and work-practices, and applied finite element analysis. From 1999-2008 she served as a Senior Scholar at the Carnegie Foundation for the Advancement of Teaching, leading the Foundation's engineering study (as reported in Educating Engineers: Designing for the Future of the Field). In addition, in 2003 Dr. Sheppard was named co-principal investigator on a National Science Foundation (NSF) grant to form the Center for the Advancement of Engineering Education (CAEE), along with faculty at the University of Washington, Colorado School of Mines, and Howard University. More recently (2011) she was named as co-PI of a national NSF innovation center (Epicenter), and leads an NSF program at Stanford on summer research experiences for high school teachers. Her industry experiences includes engineering positions at Detroit's "Big Three:" Ford Motor Company, General Motors Corporation, and Chrysler Corporation.

At Stanford she has served a chair of the faculty senate, and is currently the Associate Vice Provost for Graduate Education.

Ms. Kaye Storm, Stanford University

Kaye Storm joined Stanford University as the Director of the Office of Science Outreach in January 2008. She has campus-wide responsibility for assisting faculty to develop their Broader Impacts ideas and activities.

Prior to 2008, she was the founding Executive Director and later the Director of Special Projects at Industry Initiatives for Science and Math Education (IISME), an educational nonprofit in the San Francisco Bay Area, and Marketing Manager for the University College London, linking faculty scientists and engineers with British industry. She also created engineering graduate fellowship and Japan research fellowship programs for the American Electronics Association, a large U.S. trade association of technology companies. Her first career was as a high school teacher in Santa Clara, California and she also helped establish the Girls' Middle School in Palo Alto, California. She serves on the Advisory Council of the University of Missouri Broader Impacts Network and is co-chair of the IISME Board of Directors.

She earned a Bachelor's degree from the University of California, Santa Barbara and a Master's degree in Education from Stanford University.

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Abstract

This evaluation study explored whether K-12 teachers can influence their students to pursue STEM majors after high school, and if so, how? Each of thirteen teachers participating in the National Science Foundation's Research Experiences for Teachers (RET) program said in interviews that they can influence students to pursue science, technology, engineering, and math (STEM) degrees after high school. The research team created a survey to see if a broader sample of teachers would agree that teachers can influence students to study STEM after high school. The survey listed 18 items that might influence students to study STEM in college. Unbeknownst to respondents, each item reflected one of three factors: 1) teacher instruction and advising 2) student proclivity, and 3) student traits. The survey was completed by 215 teachers, who identified student proclivity as most influential in students' decisions whether to pursue STEM majors in college, followed by teacher instruction & advising. The authors then distributed a similar survey to high school seniors nationwide, to which 519 seniors responded who planned on attending college in the fall. Those intending to study engineering identified middle and high school instruction as significantly more influential in their choice of major than student proclivity, aptitude, and family influences. The survey also identified specific instructional and advising strategies (consistently mentioned in teacher interviews) that were significantly influential. Implications are discussed.

Introduction

The Research Experiences for Teachers (RET) program in engineering and computer science was initiated by the National Science Foundation (NSF) in 2001. RET programs are funded throughout the country (see http://www.retnetwork.org/about.php), and although the NSF is a significant funder, it is not the only funder of RET and RET-like programs. Explicit and implicit among the goals of such programs is the intention of increasing student knowledge as well as interest in pursuing STEM study and careers after high school. Within NSF, RET is considered a *Workforce Development Program*, and the program description states:

> Encouraging active participation of teachers in NSF projects is an excellent way to reach broadly into the teacher talent pool of the U.S. and *to encourage more K-12 students to pursue engineering studies* by increasing their understanding of engineering, as conveyed by their teachers. (NSF Program Solicitation (NSF 11-509) p.4, available at: http://www.nsf.gov/pubs/2003/nsf03554/nsf03554.pdf — emphasis added)

This study was conducted as part of a three-year evaluation of an NSF-funded, RET program based at a moderately-sized private university from 2010-2012. The evaluation focused on 1) whether teachers' participation in RET increased their students' interest in science, technology, engineering, and math (STEM) study and careers, and 2) if so, how? As a complement to looking at teacher beliefs, we surveyed students who planned on enrolling in engineering and other STEM majors in college regarding factors that influenced their decision. The data include interviews and surveys of RET teachers, and a survey taken by high school seniors nationally who planned on attending college within a year of graduation. Although the focus on this work was on assessing the extent to which RET experiences influence the students of RET teachers to pursue engineering and other STEM majors and careers, the research addresses broader questions regarding what motivates students to study STEM and in what ways teachers can stimulate and sustain such interest.

Literature Review

RET programs have been evaluated extensively.[1] Yet scant research exists related to the assumption that providing K-14 teachers summer internships in research labs and industry settings translates into greater interest in STEM subjects and fields among their students. Jay Dubner, Samuel C. Silverstein, and their colleagues have explored this question through controlled statistical studies and found positive gains in interest and attitudes among students whose teachers have participated in RET programs.[2] Although student interest in STEM increased as a result of their teachers' participation in RET programs, the specific mechanisms that caused this increase are not well understood.

Psychological research suggests that students' decision-making about their college and major selection is a complex process involving a broad array of variables that include and are affected by socio-economic status, student ability, students' perceptions of ability, and gender, to name a few.[3] Trusty found that patterns of middle- and high-school course-taking affect decisions whether to major in science or math, but differentially for young women as compared to young men.[4] Among females, 8th grade math test scores predicted math and science course-taking in subsequent years and eventually their choice of a math or science major. For young men, only completion of high school physics predicted their choice of a math or science major. In other words, for women, math learning was most influential in their decisions whether to pursue math or science majors, whereas for men, science learning was more influential. Also, the factors that influenced women's decisions take place much earlier than those that influenced men's decisions. Dick and Rallis also found differential influences for young men as compared to young women, but these effects were mitigated by math and science preparation.[5]

In light of Trusty's results, Betz and Hackett[6] provide an interesting contrast. They found that math self-efficacy beliefs among college undergraduates were correlated with choice of science major. In this study, women's self-efficacy for math was statistically lower than that of men, and this correlated with choice of major, even though, according to Trusty (above), high school math course-taking patterns predict women's selection of a math or science major. These and other studies[6] explore a diverse range of variables that, taken together, make it difficult to generalize what causes students to select the college majors that they do. What seems clear is that the process is complex, varies by gender and perhaps other demographic factors, and resists simple characterizations.

Although some variables may be predictive—such as a facility with computers or math course-taking among young women, the question remains as to what influences students to engage in these behaviours in the first place? Few studies address the critical underlying questions related to how students first become interested in STEM topics and what factors lead them to pursue such interests over time. Hall, Dickerson, Batts, Kauffmann, & Bosse conducted a survey study of 118 first-year through seniors in high school and 83 first-year and seniors in college to determine what influenced their decisions to pursue majors in STEM.[7] Students in both groups listed interest in the major first, followed by parents and earning potential, followed by high school teachers. The authors' results, supported by other research, suggest that developing interest in engineering or another STEM field is a critical precursor to selecting a STEM major in college, and that other influences are subordinate to initial interest.[8] Again, the question arises: how do students become interested in engineering and other STEM majors and careers?

The current study explores the link between teacher professional development and student interest in pursuing engineering and other STEM majors. The research questions were:

1) *Do teachers believe that they can influence their students' choices of undergraduate major?*
2) *If teachers believe they can have such influence over their students what is/are the mechanism(s) of this influence?*
3) *To what extent do high school seniors intending to study engineering in college report that teachers' instruction or advising influenced their choice of major?*

Method

This research comprised two sample populations: 1) in-service teachers participating in summer professional development programs (including RET), and 2) high school seniors from around the country who planned on attending college within a year of graduation. During 2010, we conducted interviews with all eight RET teachers placed at the university that summer. Interviews focused on teachers' beliefs regarding whether they can affect their students' interest in pursuing STEM majors in college, and if so, how. The following year, we interviewed five new RET teachers about the ways they believed that they influence their students towards STEM study. Both sets of interviews focused on the same questions.

Based on teachers' responses, we created the Influences on Studying STEM-Teachers (ISS-T) Survey, in which teachers were asked to rate a range of items that might influence students to pursue STEM majors in college. Included in those items were several *instructional and advising strategies* identified by teachers that had been interviewed (including the *mechanisms of influence*, cited below). Items were also included in the survey pertaining to *student proclivity for STEM*, which included aptitude and family influence. Finally, we included items related to *student traits* that are difficult to change, such as gender, ethnicity, and socio-economic status. These three types of influences were presented as individual items, not identified as teaching, student proclivity, and trait influences. The survey link was included on final evaluation surveys that went out to 155 teachers involved in summer internship programs throughout the region in 2011. Teachers were encouraged to click the link after completing the evaluation survey. The response rate was approximately 55%. The survey was re-administered in 2012 to a much broader network of teachers participating in summer internship experiences in academia and industry across the country. This survey received 125 useable responses, but a response rate was not possible to determine. Data from the two administrations were combined.

Next, we sought to gather high school students' perspectives about what influenced their decisions about a college major. In winter, 2012, we created and piloted the Influences on College Major-Student (ICM-S) Survey, which was designed to extend the inquiry as to whether teachers can influence students to study engineering specifically, as well as other STEM majors. The ICM-S survey asked students to identify factors that influenced them to choose their intended major. As with the ISS-T survey, the ICM-S survey had embedded in it combinations of *teacher instruction and advising* factors and *student proclivity* factors, including aptitude and family influence (trait factors were not included, since we couldn't think of a way to ask respondents if being male or middle-class or white was a significant influence in their choice of major).

The student survey was piloted using a sample of 209 high school students in a university-based summer program. After the survey was refined, the link was distributed widely to high school students around the country, using an extensive regional and national professional network. Nearly 1,000 students responded, 519 of whom reported being high school seniors intending to enroll in college within the year. Of the 519, 506 reported an intended major. Of the 506, 194 (38.3%) reported intentions to major in engineering, 173 (34.2%) reported intending to pursue science, technology, math (other STEM) majors, and 139 (27.5%) reported intentions to pursue non-STEM majors.

Results of Teacher Interviews & Surveys

Teacher Interviews: 2010, 2011

During 2010 and 2011, we conducted interviews with 13 RET teachers. All teachers we interviewed believed that they can and do influence at least some students to pursue STEM study and careers. Representative comments include:

Researcher: What kind of major/career influence do you have on your students?

> JK: Mostly, I think a lot. …It's the tenth year I'm teaching the class. I would say, about a quarter of my total kids have majored in some sort of environmental science, conservation, something related to the environment. So, obviously a little bit of influence.[i]
>
> JB: Well, if they're my AVID[ii] kids, [I'm] definitely helping them go to college, and helping them choose that college. With my freshmen, hopefully I'm continuing their interest in science enough for them to keep going. I don't think I'm directly influential with the freshmen, except for science club. If they come in to science club, I've just been doing my own analysis of where they go to college, and a lot of those kids go into science.
>
> AS: I would say I have a huge influence [over my 5th, 6th, and 7th grade students]. … I believe that all kids that come in should have a math and science experience, and so even those kids that come in that are [not math-oriented], they're going to get it, whether they're ready or not. …I find that a lot say, 'Wow, it was easy to learn this from you, when I haven't been able to learn it from other teachers.' So, I've had the opportunity to motivate a lot of kids towards math and science.

Teachers suggested that their influence varies based on students' motivation for college, intellectual proclivities, what class they are enrolled in (e.g., general science vs. AP or AVID), and by the proximity of students to their senior year. But all teachers with whom we spoke believed that they have at least some influence on at least some students' decisions to study and/or pursue STEM-related fields and careers.

Mechanisms of Influence

If teachers believe they can influence students towards STEM careers, how does this happen? There was remarkable convergence across the interview data regarding how teachers perceived that they influence their students to study STEM. Teachers commonly cited four strategies, which we refer to as Mechanisms of Influence (MI's):

1) Implementing curricular and extra-curricular activities (including, for example, field trips) that give students hands-on experiences or enable them to see and/or experience science and engineering in action, and in ways that relate directly to their personal lives;
2) Bringing STEM professionals to class or providing other means by which students can talk directly to professionals with STEM careers;
3) Sharing science and engineering anecdotes and personal experiences in class and when meeting with students in one-on-one and small group interactions; and
4) Alerting students to STEM-oriented programs within and outside of school in which they (students) can participate.

After exploring *how* teachers influence students towards STEM, we asked them to speculate *why* they believe that the *mechanisms of influence* they described have the effect of motivating students to pursue STEM study and careers. Teachers believed that engaging students in authentic, personally relevant, STEM-related experiences and activities promotes a personal connection to STEM disciplines that motivates students to deepen their engagement by taking more classes or pursuing STEM-related opportunities. The following teacher's comment is representative of many that teachers provided in interviews:

> BS: I think [what motivates students] is when they can get first hand experiences and latch onto something tangible in their own lives they can relate to. Any time that you can make connections to their everyday lives, that will bring a more tangible sense of what is going on in research and what tends to be the most authentic to them.

Another teacher simply said:

> JN: You have to give students opportunities to *do* science, not just sit and learn it.

The need for students to experience personally relevant, engaging, and authentic science and engineering content and practices was a thread that wove throughout the four MI's. Teachers suggested that if students are hooked by science curriculum, they will be motivated to study the subject as they progress towards their senior year, in college, and afterwards. Hands-on curriculum, teachers' anecdotes, and participating in STEM-related out-of-class/out-of-school activities all provide students ways to personalize science and engineering content and practices.

From Interviews to Survey Items

The study team distilled interview responses into six survey items that we labeled *Teacher Factors*. We then created another six items related to student ability and exposure that we labeled *Student Proclivity*. We created another six items related to *Trait Factors,* which have to do with demographic and socio-economic factors that in the literature have been associated with STEM study and careers (see Table 1.) We then jumbled up these 18 items and asked teachers to rate the extent to which they believe each item contributes to a student's pursuit of STEM study. Response options were *Not at All, Minimally, Moderately,* and *Extensively* (scored on a 1-4 scale).

We administered the survey two times, once in 2011 and once in 2012. In the 2012 version we included the question, "Have you taken this survey before?" The link was sent out on multiple teacher networks, so a response rate could not be calculated. We eliminated from the 2012 analyses teachers who reported they had taken the survey before or weren't sure whether they had, which resulted in a total combined useable sample across the two years of 215 teachers.

The samples across the two years were very similar. Seventeen percent of 2012 teachers taught middle school and 83 percent taught high school. The 2011 sample included 8 percent elementary teachers, 17 percent middle school, and 75 percent high school teachers. Average of total years teaching was 23 for the 2012 sample, compared to 18 for the previous year's sample. The main subject reported taught by 64 percent of 2012 teachers was science, followed by 22 percent in math, with the rest reporting English (2 percent), social studies (1 percent) or other (10 percent). This is nearly identical to the previous year's sample. Thirty-six percent of 2012 teachers reported teaching in urban schools, 49 percent in suburban, 14 percent urban-suburban, and 1 percent in rural schools. This distribution was very similar to the previous year's teachers. In both samples, the median percentage of students participating in Free and Reduced Price Meals (FRL) was 25 percent.

Teacher Survey Results

Survey analyses are based on 215 respondents. As we had hoped, factor analyses of the items resulted in 3 distinct factors: (1) Instruction & Advising; (2) Student Propensity (3) Student Traits. We created 3 scales based on the factor analyses; they are described in Table 1, below.

Table 1. Teacher, Student, and Environment Scales, items, means, and standard deviations, 2011 and 2012 deployment (n=215)

Scale (Cronbach's alpha)	**ITEMS**	**Mean (SD)**
Student Propensity (α=0.67)	1. Students get good grades in STEM courses. 2. Students have family members and/or close friends/relatives who work in STEM jobs/careers. 3. Students' families influence them towards STEM. 4. Students have natural proclivity towards STEM disciplines.	3.41 (0.47)
Teacher Instruction & Advising (α=0.79)	1. Teachers have integrated current STEM research into classroom lessons. 2. Teachers have used inquiry-based activities in STEM classes. 3. Teachers have brought practicing STEM professionals into the classroom. 4. Teachers have related personal anecdotes related to STEM jobs and/or research. 5. Teachers have advised students about STEM-related courses they can take in school. 6. Teachers have alerted students to STEM-related jobs and/or out-of-school activities.	3.13 (0.48)
Student Traits (α=0.80)	1. Students are white. 2. Students are male. 3. Students are middle or high socioeconomic status. 4. Students attend high schools with low proportion of students who participate in a Free and Reduced Price Meal program.	2.38 (0.69)

The Student Propensity factor was rated most influential ($\bar{x}$=3.41), followed by Teacher Instruction & Advising ($\bar{x}$=3.13), and the Student Trait factor ($\bar{x}$=2.38). The differences between the means on these factors were statistically significant at $p<.01$. Trait factors are those that are least amenable to change, such as race, gender, SES. Since we would not wish teachers to think that STEM study after high school is based on race and gender, for example, it was a positive finding that these factors were considered by teachers to be least influential. In fact, some respondents were offended that these items were included in the survey.

Based on the teacher ratings of their self-efficacy for influencing students' decision to study STEM (i.e., the item: *I believe that as a teacher I can influence students to study STEM after high school*), we classified teachers into two groups: high self-efficacy (HSE) and low self-efficacy (LSE). Teachers with HSE rated the importance of teacher factors significantly higher than teachers with LSE. The means for these two groups were 3.3 and 3.0 respectively ($p<.01$), indicating that HSE teachers believed that instruction was more influential in students' decision-making than LSE teachers. In spite of this difference, the ordering of factors did not change. All teachers indicated that Student Propensity exerts the strongest influence, followed by Teacher Instruction & Advising, followed by Student Traits. Thus, teachers reported that Student Propensity is the most influential factor that determines whether students pursue STEM majors after high school. Next we asked students what they think.

What Factors Do High School Seniors Report Influence Their Decision to Study Engineering in College?

In 2012, we created and piloted the *Influences on College Major—Students (ICM-S) Survey*, in which students were asked to rate the influence of several factors leading to their intended major in college. The survey was piloted in February 2012 through teachers whose students would not be expected to encounter the actual survey that was being deployed later that spring. The pilot yielded 209 responses and resulted in trimming and improving some items. The final version was deployed from mid-March through the end of May, 2012. The survey was administered online via Survey Monkey. The link was distributed to students by their teachers through several local and national teacher networks. As a result, a response rate could not be calculated. Responses (which were anonymous) were received from nearly 1,000 students from across the country.

Table 2. Influence on College Major—Students: scales, items, and reliabilities

Scale	# Items	Cronbach α
Middle school instruction on choice of intended major	8	.85
High school instruction on my choice of intended major	8	.89
Perceived aptitude or talent for the intended major	4	.60
Motivation for the major	3	.85
Attitude towards intended major	4	.92
Concerns about intended major	3	.61
Influences of other people	4	.81
Outside activities related to intended major	3	.64
All items combined	**37**	**.86**

The ICM-S is comprised of 8 scales, each of which can influence a choice of college major. Response options are all on a four-point scale, 1=*Not at All*, 2=*Rarely*, 3=*Sometimes*, 4=*Often*.[iii] Scales and reliabilities are shown in Table 2. Using logistic regression, we compared students reporting an intention to major in engineering (Engr) with those who reported an intention to major in other STEM (STM) degrees. Seniors who chose Engr were coded as ‘1’ and those who chose STM were coded as ‘0’. We first used the 8 scales of our survey to predict choice of major. We regressed choice of major (i.e., Engr/STM) on the 8 scales. If a scale result was significant, we then regressed choice of major on the specific items of the scale in order to identify which items explained a statistically significant portion of the variance. Then we disaggregated the data by gender, ethnicity, and mother’s level of education and carried out the same iterative analysis strategy. This analysis used logistic regression to determine the principal influences on choice of major when the seniors were broken down into two groups – Engineering (Engr) vs. STM (non-E).

Sample

A total of 936 valid responses were received from high school students in which items were completed pertaining to influences on choice of major. Of these, 519 were seniors, and the analysis below is based on this senior sample. There were a total of 367 seniors in this analysis, 194 Engr, 173STM.

Of the 519 seniors, 451 reported their gender. Gender frequencies are shown in Table 3.

Table 3. High school seniors’ gender

		Frequency	Valid Percent
	Female	186	41.2
	Male	265	58.8
	Total	451	100.0
Missing	System	68	
Total		519	

Mother’s education level is often considered a proxy for socio-economic status. The distribution on this item is shown in Table 4, below.

Table 4. High school seniors’ reported mother’s highest education

		Frequency	Valid Percent
	HS or Less	150	36.0
	2- or 4-Year Degree	191	45.8
	Master’s/ Ph.D./ Terminal Degree	76	18.2
	Total	417	100.0
	Missing	102	
Total		519	

Racial composition of the sample is shown in Table 5, below.

Table 5. Reported ethnic composition of high school seniors

	Ethnicity	Frequency	Valid Percent
	African American	58	13.2%
	White	247	56.4%
	Hispanic	59	13.5%
	Asian	48	11.0%
	Pacific Islander	12	2.7%
	Middle Eastern	6	1.4%
	Native American	2	0.5%
	Other	6	1.4%
	Total	438	100.0
Missing	System	81	
Total		519	

Ethnicity was recoded into non-underrepresented minority (N-URM—White and Asian) and Underrepresented Minority (URM—all others) and See table 6, below.

Table 6. Underrepresented minorities (URM) and non-underrepresented minorities (N-URM)

	Ethnicity	Frequency	Valid Percent
	URM	143	32.6%
	N-URM	295	67.4%
	Total	438	100.0%
Missing	System	81	
Total		519	

Among 519 seniors, 506 provided information about their prospective majors. Of those, 367 (72.7 percent) reported an intention to study a STEM major and 139 (27.3 percent) reported an intention to study a non-STEM major. Determination of STEM was made based on intended major (see Table 7, below).

Table 7. Frequencies of intended majors reported by high school seniors

	Intended Majors	Frequency	Valid Percent
	Biological Sciences (S)	109	21.6%
	Natural/Physical Sciences (S)	15	3.0%
	Humanities	18	3.6%
	Engineering (S)	194	38.4%
	Math/Computer Science/Technology (S)	49	9.7%
	Social Sciences	44	8.7%
	Other (non-STEM)	77	15.0%
	Total	506	100.0%
Missing	System	13	
Total		519	

(S)=Majors that were identified as STEM

Results

The 8 scales in this analysis explain 14 percent of the variance in choice of Engr vs STM (strong effect size). *High School Instruction* (*HIS)* emerged as a significant influence over the choice of major. *Middle School Instruction* (*MSI)* was also a significant correlate of choice of major, as was the *Concerns* scale. Students planning on engineering expressed concern about the *difficulty of the major* (not about *lack of free time* or *program will take longer*). The difference between Engr and STM regarding *difficulty* is statistically significant (p<.01).[iii]

Within the HSI and MSI scales, two items emerged as significant. W*e read books, watched movies, or studied current events related to major* were instructional activities that were rated as more influential by those intending to study STM vs. Engr. Also in both *MSI* and *HSI, a professional in the field visited the classroom* was more influential to those considering Engr vs. STM majors. (All differences significant at p<.01). Results of Engr vs. STM comparisons are summarized in Table 8, below. [iv]

Table 8. Engr vs. STM: Means & SDs on significant variables on MSI, HSI and Concerns scales

	MSI: Professionals visited the classroom. **Mean (SD)**	***MSI: We read books, watched movies, or studied current events related to major.*** **Mean (SD)**	***HSI: Professionals visited the classroom.*** **Mean (SD)**	***HSI: We read books, watched movies, or studied current events related to major.*** **Mean (SD)**	***Concerns: Difficulty of the major.*** **Mean (SD)**
STM (n=173)	1.41 (.989)	2.36** (.929)	2.37 (.693)	2.96** (.831)	2.93 (1.42)
Engr (n=194)	1.54** (.927)	1.78 (.950)	2.70** (.778)	2.78 (.842)	3.17* (1.41)

*Differences significant at p<.05. **Differences significant at p<.01.

No differences emerged when we disaggregated the data by gender or mother's education. Comparisons between URM's and nURM's were not possible because of too few URM's in the sample.

Table 9. Engineering vs. STM (no E): Means and SDs on MSI & HSI scale items

High School Instruction (HSI) Items	***STM Mean (SD)***	***E Mean (SD)***
In HS, teachers shared current research, literature, or innovations related to my major.	3.25 (.782)	3.36 (.851)
In HS, classes involved hands-on activities and/or projects related to my major.	3.35 (.905)	3.46 (.907)
In HS, we read books, watched movies, or studied current events related to my major.	2.96* (.831)	2.78 (.842)
In HS, we studied topics in my major that related to my life.	3.15 (.868)	3.16 (.842)
In MS, professionals from my major visited class.	2.37 (.693)	2.70* (.778)
In HS, a teacher advised me about jobs and careers related to my major.	2.94 (.935)	3.20 (.925)
In HS, a teacher related personal stories related to my major.	2.94 (.906)	3.09 (.861)
In HS, a teacher alerted me to out of school activities in my major.	2.67 (.882)	2.81 (.890)
Middle School Instruction (MSI) Items	***STM Mean (SD)***	***E Mean (SD)***
In MS, teachers shared current research, literature, or innovations related to my major.	2.48 (.837)	2.22 (.825)
In MS, classes involved hands-on activities and/or projects related to my major.	2.56 (.839)	2.32 (.747)
In MS, we read books, watched movies, or studied current events related to my major.	2.36* (.929)	1.78 (.950)
In MS, we studied topics in my major that related to my life.	2.22 (.928)	1.82 (.820)
In MS, professionals from my major visited class.	1.41 (.989)	1.54* (.927)
In MS, a teacher advised me about jobs and careers related to my major.	1.79 (1.09)	1.86 (.924)
In MS, a teacher related personal stories related to my major.	1.87 (.998)	1.69 (.875)
In MS, a teacher alerted me to out-of-school activities in my major.	1.64 (1.09)	1.67 (.944)

*Differences significant in logistical regression analyses at $p<.01$

Summary of ICM-S Survey Data

In this study of the influences on choice of major as reported by a sample of 519 high school seniors, the most notable finding is that students consistently rated *High School* and *Middle School Instruction* as significant influences over their choice to major in engineering. These results held for students choosing other STM majors as well. Instructional factors were more influential in students' choice of college major than influences coming from *peers, parents, outside activities, attitudes and beliefs about the major, perceptions of aptitude, interest* or *enjoyment*.

Students intending to study Engr reported that *professionals visiting the classroom* in both middle- and high school was significantly more influential than other instructional activities in their choice of major. The variable, *we read books, watched movies, or studied current events related to major* was significantly more influential to students intending to study other STM compared to Engr.

Some nuances emerged when the data were disaggregated by demographic variables. Yet in spite of differences in specific items that would be difficult to explain, the overall pattern of results held: middle and high school instruction exerted a significant influence over all students' interest in pursuing engineering vs. other STM majors.

We believe that the closer one looks at these results, the more meaningful they seem. The statistical technique we used, logistic regression, accounts for the variance of all variables in the equation, which has the effect of minimizing differences between individual variables. If we only compare means item by item, we see differences that might have been significant if we had used a t-test analysis. We did not feel that for the specific question we were asking (i.e., whether major choice can be predicted) this would be an appropriate test statistic. But as Table 9 shows, means on several *MSI* and *HSI* scale items actually have larger observed differences than those for which correlations were found to be statistically significant. Furthermore, some of these differences are more meaningful. Keeping in mind survey responses were on a 4-point scale, means less than 2.5 lean toward *rarely* or *never*, while means above 2.5 lean towards *sometimes* and *frequently*. The most meaningful differences would be those that separate groups below and above 2.5. The tables below show mean differences on individual items that comprise the *MSI* and *HSI* scales, which were found to be predictive of major choices.

Limitations

We believe that our results are intriguing and suggest the value of pursuing this line of inquiry. However, our results have limitations that make our findings suggestive rather than definitive. We have administered the ISS-Teacher survey for two years and believe that the instrument is tight and highly reliable. However, in both administrations, teacher respondents reflect professionally engaged teachers participating in competitive, summer professional development programs. A broader sample of teachers would likely produce more nuanced findings.

The ICM-Student survey has been administered once (after piloting). Reliabilities of most scales, but not all, are good. We have scrutinized the patterns of results and have ideas for both shortening and strengthening the instrument. Responses were acquired from a convenience sample, rather than a purposeful sampling plan. We see fluctuating patterns of results and broader standard deviations than we'd like. Indications from our item-level analyses are that strengthening the instrument and obtaining a more purposeful student sample would probably address these limitations. It was for these reasons that we conducted rigorous analyses and have been conservative in our assessments of what we have found and not found to be statistically significant. In spite of the limitations of the current study, significant findings emerged that we are confident reflect a relatively unexplored phenomenon, and are not an artifact of the survey instrument.

Summary & Implications

The research team conducted interviews with 13 RET teachers, asking whether they believe that they can influence students' decisions to pursue STEM in college. Every teacher believed that she or he could do so. When asked *how* they do this, teachers' responses fell into the following four strategies, or *mechanisms of influence (MI's)*:

1) Implementing curricular and extra-curricular activities (including, for example, field trips) that give students hands-on experiences or enable them to see and/or experience science and engineering in action, and in ways that relate directly to their personal lives;
2) Bringing STEM professionals to class or providing other means by which students can talk directly to professionals with STEM careers;
3) Sharing science and engineering anecdotes and personal experiences in class and when meeting with students in one-on-one and small group interactions; and
4) Alerting students to STEM-oriented programs within and outside of school in which they (students) can participate.

When asked *why* these strategies are effective, teachers' comments revolved around the importance of connecting STEM to students' lives, and engaging students in authentic, STEM experiences and activities.

Based on these qualitative findings, we created and deployed two surveys:

1) *Influence on STEM Study—Teacher Survey* (2011, 2012), based on teacher interviews, in which teachers rated the extent to which they believe specific Teacher Instruction & Advising, Student Proclivity, and Student Trait factors influence students to pursue STEM majors and careers.
2) *Influence on College Major—Student Survey* (2012), in which 519 high school seniors identified factors that influenced them to study particular majors (mostly engineering and STM) in college.

On the ISS-T survey, teachers identified the *Student Proclivity* as being significantly more influential in students' decision to pursue STEM study and careers than *Teacher Instruction & Advising*, which were both deemed to be significantly more influential than *Student Traits.*

The ICM-S sought to identify what high school seniors say influences them to study engineering and other STEM majors in college. In contrast to teachers' beliefs that student proclivities predominately influence students to study STEM after high school, students who report intentions to study engineering in college overwhelmingly reported that *Middle* and *High School Instruction* influenced their choice of major. In addition, students who selected engineering were significantly more likely to express concerns about the difficulty of the engineering major compared to students interested in other STM fields.

Our study provides evidence from the ISS-T survey that teachers in RET-like programs believe that engaging students in authentic, personally relevant STEM experiences influences those students to study engineering and other STEM majors after high school. We have evidence from the ICM-S survey that students' decisions to study STEM in college can be directly influenced by classroom instruction and teacher advising. We also have evidence from the ISS-T that teachers underestimate the effect that classroom instruction can have on students' decisions whether to pursue STEM after high school.

Hall et al., cited earlier,[7] found that teachers were the fourth greatest influence over students' decisions to major in engineering and other STEM majors. The highest rated factor was student interest. It would be interesting to know where the students in their study and the current one first developed their interests. To what extent were students first introduced to engineering and other STEM majors by their teachers? In our current study, students reported that *reading books, watching movies, and studying current events* and *having professionals visit the classroom* exerted a statistically significant influence on their decisions to pursue engineering and other STEM majors. The impact of such activities might be evaluated in light of the fact that teachers and school counselors have been found to have little knowledge of engineering and other STEM majors.[7,9] Is it through school assignments and activities that students become acquainted with what engineering is and what engineers do? We hypothesize that many students who eventually pursue engineering and other STEM majors get their first exposure to these fields in school. Research and policy documents encourage K-12 teachers to promote engineering design experiences for their students because such experiences deepen learning, but they are also a means by which to engage students in and excite them about the subject matter. The impact of such experiences can be long-lasting.[10]

What are possible practical implications of this line of research?

- This study builds on research and policy that suggests the value of early exposure to engineering, including hands-on design-oriented experiences. Might it be possible to identify a collection of evidence-based, pedagogical strategies that have been proven through research to inspire students to study particular majors after high school? Can we use this research to reach young women, students from lower SES communities, and underrepresented minorities to diversify the STEM disciplines?[10]
- Teachers know that they influence students to pursue engineering and other STEM majors after high school. But many underestimate the impact of instruction that exposes students to the kinds of problems that engineers solve and the methods they use. Alerting teachers to the impact of engaging, introductory experiences and subsequent follow up increases the possibility of igniting students' interest in engineering. This could have disproportional benefits to low income populations, who might have limited contact with engineering professionals, and to young women, who might not, initially, consider engineering a field in which they might be interested or successful.
- This study suggests rich possibilities for further study into K-12 career decision-making. Students considering engineering majors were significantly more likely to report concerns about the difficulty of the major compared to students considering other STEM majors. Further study might enable K-14 educators to better anticipate

and address students' concerns and expectations and therefore boost recruitment and retention in STEM.

The authors believe that this preliminary inquiry warrants further exploration into how student interest in a field of study begins and is supported in and out of school. We hope to conduct follow-up studies in the future with students and teachers to deepen this inquiry into how teachers can motivate students to study engineering and other STEM majors after high school.

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[i] All initials are based on pseudonyms.
[ii] AVID (Advancement Via Individual Determination) is a nationwide college readiness program (see www.avid.org).
[iii] In the survey, students were asked to respond to an item asking about *frequency* of an activity (*never* to *often*), followed by an item about *influence* of the activity (*not at all influential* to *extremely influential*). Invariably, the two were highly correlated (above r=.80). In future administrations, we would rephrase the questions so that only one would be asked. In these analyses, we focused on the frequency items, because they showed slightly more variability. However, we do not believe that students' responses are accurate reflections about actual frequency, especially since we didn't provide a metric for the four response options; rather, we interpret responses as reflections of students' perception of the influence of these events.
[iv] In other analyses that are not the subject of this paper, we found that HSI was significantly more influential to students intending to study STEM majors compared to those studying non-STEM majors. The two items within HSI that were found to be significantly different were *hands-on activities/projects related to the major* and *we read books, watched movies, and/or studied current events related to the major*.