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Dr. Nathan's research is largely rooted in cognitive, embodied and social perspectives on learning and instruction, and employs quantitative and qualitative methods. Currently, he examines the intersection of student and teacher cognition as it plays out in classroom learning situations, primarily involving middle and high school mathematics, science and engineering. His research on students' reasoning showed that they may invent effective strategies and representations for solving math problems, and these methods can serve as bridges for instruction. He is also exploring the embodied nature of students' knowledge, as exhibited by gestures, and the mediating effects of action on conceptual knowledge. His studies of teachers' beliefs about the development of students' mathematical reasoning showed that content experts can show evidence of expert blind spot, which influences teachers' expectations of what makes things difficult for their students.

He is currently co-principal investigator for the AWAKEN Project (funded by NSF-EEP), which examines the nature of high school pre-engineering, early college engineering, and professional engineering practice in order to foster a more diverse and more able pool of engineering students and practitioners.

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High School Teachers' Beliefs about Engineering Preparation

Abstract

Instructional practice and teacher decision making are influenced by teachers' beliefs about learning and instruction. The primary goal of this study is to develop a statistically reliable survey instrument ($\alpha \geq .70$) that documents teachers' beliefs and expectations about high school pre-engineering instruction and preparation for students' future success in college engineering programs and careers in engineering. The secondary goal is to examine how teachers would advise students described in vignettes with varying achievement, gender, ethnic and socio-economic profiles who are seeking to pursue future studies and careers in engineering and related technical fields. To achieve these goals we developed the Engineering Education Beliefs and Expectations Instrument (EEBEI) and administered it to high school STEM teachers (N = 144) of science, mathematics and pre-engineering classes. Teachers indicated that engineering preparation takes place in multiple contexts, including academic and technical education classes, as well as home, community and workplace settings. Teachers generally believe that to become an engineer a student must show high academic achievement in their math, science and technology courses. Teachers also believe that having a parent as an engineer increases a student's likelihood of becoming one, as does being male and either white or Asian. While, socio-economic status (SES) was not reported as an important consideration for determining student preparation when teachers were explicitly asked, it emerged as an influential factor when it was implicit in situated decision-making using student vignettes. Comparisons between fictional students with varying economic and social background but comparable academic performance histories suggest that SES did influence teachers' endorsements for student pre-engineering enrollment and for predicting a student's future success in the engineering profession. By establishing a reliable instrument that measures teachers' beliefs and expectations about high school pre-engineering instruction and preparation for students' future success engineering, we hope to contribute to the wide scale efforts currently in place to expand and improve engineering education and foster a more technologically advanced society.

Introduction

Education research shows that instructional practice and teacher decision making are influenced by teachers' beliefs about learning and instruction[1, 2, 3]. The primary goal of this current study is to develop a statistically reliable survey instrument that documents teachers' beliefs and expectations about high school pre-engineering instruction and preparation for students' future success in college engineering programs and careers in engineering. In pursuing this goal we strive to operationalize several psychological constructs--beliefs, attitudes and expectations for engineering studies--and show how they relate to teacher decision-making regarding their instructional practices. We call this general survey the Engineering Education Beliefs and Expectations Instrument (EEBEI, pronounced "eebee"). The secondary goal is to examine how teachers would advise students described in vignettes with varying achievement, gender, ethnic and socio-economic profiles who are seeking to pursue future studies and careers in engineering and related technical fields. The teachers in our study included high school science, math, and technical education teachers. The technical education teachers all used *Project Lead the Way* (PLTW) pre-engineering program, which we describe in more detail below.

We are able to report that these goals were successfully achieved. To situate this work, we first review some of the prior research on teacher beliefs more broadly, and on the work done specifically in engineering education. We then lay out our specific research questions and describe the methods we used to address these questions. We report results from our initial administration of the EEBEI showing it to be a statistically reliable instrument for assessing teachers' beliefs about engineering education and preparation. We conclude with a discussion of the importance of studying teacher beliefs for engineering education and educational reform.

Prior Research on Teacher Beliefs

Teachers generally report that their perceptions of students are the most important factors in instructional planning, and teachers consider their views of student ability to be the characteristic that has greatest influence on their planning decisions[4, 5]. Furthermore, teacher beliefs have an impact on students' educational experiences [1, 6, 7]. Yet beliefs about learning and instruction are mental constructions mediated by culture and social influences, rather than directly rooted in scientific evidence[8, 9]. As such, teachers' beliefs and expectations of students' knowledge and behaviors are not always accurate or consistent with educational reform principles[3, 10]. Consequently, teacher educators and educational researchers need to be able to design educational programs directed at belief change. Understanding the beliefs held by educators is central to affecting change and improving instruction[11, 12].

Many of the themes that have been addressed in education more broadly, also apply to teacher beliefs about engineering education. For effective reform to take place within engineering education, it is necessary to incorporate teachers' attitudes and beliefs about instruction and learning[13]. Furthermore, as part of the growing need to better understand and improve learning and instruction within engineering education, there is an awareness of an increased need to understand learners and teachers[14]. In a recent statement laying out the research agenda for the field of engineering education[15], the *Journal of Engineering Education* editorial board highlighted the need to understand the "engineering teaching culture."

However, much of the research on teachers and teacher beliefs about engineering education has been specific to higher education programs of instruction[13, 16]. One notable exception is work by Yasar and colleagues[17] on K-12 teachers' knowledge and perceptions of engineers and engineering practice. The emphases of their research were to: document the importance of teaching design, engineering and technology; determine teachers' familiarity with engineering and design; investigate teachers' perceptions of engineers; and document teachers' perceptions of the characteristics of engineering practices. The authors argue that knowledge of teachers' views in this area is a necessary precursor toward developing long-range plans to better infuse K-12 education with an understanding of technology and design.

The current work draws from and extends this prior research. Our long-term aims are to improve K-16 STEM teaching and provide more effective curriculum programs for engineering and other technical fields. Like Yasar and colleagues, we argue for the value of documenting K-12 teachers' beliefs about engineering education as a prerequisite for making informed and lasting changes to engineering education. Our emphasis is complementary to theirs, as will be apparent, in that we place greater emphasis on teachers' beliefs and expectations of what constitutes appropriate engineering preparation for students, and teachers' perceived influences on their own classroom instruction.

Research Questions

We were motivated by two central questions. First, we wanted to design and field test a reliable statistical instrument that could measure the degree to which teachers exhibited certain beliefs, attitudes and expectations about their own instructional practices, the technical preparation of their students, and the factors that teachers perceived as critical for success in future engineering studies and careers. Second, we presented all of the teachers with extended vignettes portraying students with different academic, ethnic, gender and socio-economic profiles, in order to see how teachers advised these fictitious students with regard to future pre-engineering course enrollment, and to make predictions about the level of success these students are likely to achieve were they to pursue advanced engineering studies and technical careers. In addition, the vignettes focus on two of the major factors considered to be important for student success in engineering studies and careers: student academic performance and social background.

Research Methods

Instrument Development

Surveys can be thought of as instruments designed to measure latent psychological constructs that mediate teachers' views and actions. While we can never really know these psychological constructs directly, elements of the survey--collections of individual items, which, following norms from experimental psychology, we will call *constructs*--can be used as proxy measures for these views.

The EEBIE survey measures teachers' beliefs and attitudes indirectly, by examining the degree to which they agree or disagree (along a scaled continuum of responses) with statements pertaining to the views in question. Because of the indirect nature of these measures, and their inherent subjectivity, investigators strive to show that the constructs are sufficiently reliable. By *reliability*, we mean that there is consistency in the measurements. We set out to determine reliability through *internal consistency*, by presenting high school math, science, and technology education (STEM) teachers a collection of similar but non-identical statements about the views of interest, and soliciting their level of agreement. In statistics, reliability is often computed using Cronbach's alpha[24], an estimated value ranging from 0 to 1, that measures the degree to which the differently worded statements correlate. The closer this value is to 1.0, the higher the reliability estimate for the constructs under investigation. A value above .60 is acceptable in most contexts, with a value above .80 shows very strong reliability for the scale.

The survey was developed by members of the research team through an iterative process. The team included: a faculty member with degrees in cognitive psychology and engineering who studies the cognitive and social processes involved in STEM teaching and learning; a director of the Center on Education and Work at the research institution with extensive knowledge on technical education; and two graduate research assistants with backgrounds in secondary science education and outreach initiatives for engineering professional development. Two members of the group also had prior experience with the *Project Lead the Way* program. Drawing on the researchers' diverse backgrounds and professional experiences, we developed the first draft of the survey during a series of meetings in which the researchers discussed the elements related to engineering preparation at the high school and college levels.

Feedback on the first draft was provided by a team of four engineering professors and a graduate research assistant from the College of Engineering. Their comments on the content as well as the format helped in the generation of the second draft of the survey, which was field tested by volunteer technical education teachers and the program director from the local school district. Using the feedback provided by the researchers and educators, we developed a 118-item questionnaire, with each item representing teacher's beliefs and knowledge related to engineering studies and careers (e.g., to be an engineer a student must have high overall academic achievement). We constructed items using Likert scales for agreement from 1 (*strongly disagree*) to 7 (*strongly agree*), and scales for frequency from 1 (*never*) to 5 (*almost always*). Survey respondents were asked to rate the degree to which he or she agreed or disagreed with a statement and the frequency of their instructional practice (e.g., the *math* c*ontent* being taught in my courses is explicitly connected to engineering). We also created four vignettes and asked teachers to predict the likelihood of success in post-secondary engineering studies and careers for four fictional students using student background information. In addition, we asked the respondents to provide information on their years of teaching experience, grade level and subject they taught, gender, and race.

Participants

The teacher sample included high school STEM instructors from the Midwestern US, including high school mathematics, science, and technical education teachers. Names were obtained through the state Department of Public Instruction. The technical education teachers all used *Project Lead the Way* (PLTW), a pre-engineering curriculum designed to integrate math, science, and technology into the students' academic program of study. The *PLTW* high school program, *Pathway to Engineering*™, offers seven high school courses accredited for college credit, including three one-year foundation courses (*Introduction to Engineering Design, Principles of Engineering,* and *Digital Electronics*) as well as specialization courses (*Aerospace Engineering, Biotechnical Engineering, Civil Engineering and Architecture,* and *Computer Integrated Manufacturing*). In addition, there is an engineering research capstone course, *Engineering Design & Development*[18]. The *PLTW* program has been adopted by over 15% of US high schools, and is present in all 50 states. Thus *PLTW* is a widely adopted curriculum, and findings based on its use have far-reaching implications.

We originally obtained 168 responses, however, 24 of them contained missing information on at least one of the construct items. This led to a final sample size of 144 complete responses used for the major analysis. The majority of respondents in the initial sample were white (93.5%) and male (57.7%). One-third of respondents were from urban areas. Of the teachers, 58% were male and 42% were female; 36% taught *PLTW* courses and 41% taught math and 65% science courses (percentages may not add up to 100 because one teacher may teach more than one courses). Our sample shows that 47% of these teachers attained a Bachelor's as their highest degree, 51% attained a Master's degree, and 2% a Doctoral degree. Of the teachers who responded to the survey questionnaire, 11% had taught for at most 3 years, 29% had taught 4-10 years, 33% had taught 11-20 years, and 27% had more than 20 years of teaching experience.

Materials and Procedure

We refer to this specific survey as the EEBIE-T to designate its use for K-12 teachers (in other studies we are examining its effectiveness for guidance counselors and for instructors of higher education). The administration of the EEBIE-T was performed online for all participants, using a secure system provided by the university. Participants read through a consent statement, following standard procedures for working with human subjects. All participants were offered $10 in compensation for their efforts.

Respondents received 92 items in common: 68 items included in 9 constructs, 16 items for the four vignettes, and 8 demographic items. This analysis focuses on 77 items (53 items for the 7 constructs, 16 vignette items, and 8 demographic items) the respondent reported because these items best represent factors related to engineering preparation and are most appropriate for the scope of this paper. The remaining items in the survey collected information about teachers' goals, factors that influence their teaching, and teachers' perceptions of the benefits and advantages of enrollment in *PLTW*, which will be used in future analyses. Below are example items used in the survey. A 5-point scale (with a midpoint of 3) was used for rating the *frequency* of events stated in some survey items. For example, Item 8a shows a statement followed by the 5 choices, with the verbal anchors for each scale score shown in parentheses:

> Item 8a. The math content being taught in my courses is explicitly connected to engineering.
>
> 1 (Never) 2 (Almost Never) 3 (Sometimes) 4 (Often) 5 (Almost Always)

A 7-point scale (with a midpoint of 4) was used for rating the level of *agreement* with statements. For example, Item 6a shows a statement followed by the 7 choices, with the verbal anchors for each scale score shown in parentheses:

> Item 6a. To be an engineer a student must have high overall academic achievement.
>
> 1 (Strongly disagree) 2 (Disagree) 3 (Somewhat disagree) 4 (Neutral)
> 5 (Somewhat agree) 6 (Agree) 7 (Strongly agree)

Teachers selected the "radio button" that best matched the degree to which each statement matched their own views. The on-line system ensured that only given rating choices were selected (no intermediate values were possible), and that no item was skipped (the system required a response to every item before preceding). Because space on a page was not a factor for the on-line presentation, every item was accompanied by the complete set of verbal anchors for every numerical choice, thus minimizing errors that might be due to forgetting or reversing of the scales.

In addition to the Likert scale items, teachers were presented with four vignettes and asked to predict the likelihood of success in post-secondary engineering studies and careers for four fictional students using course grades, gender, ethnicity, family income, technical experiences in and out of school, and engineering interests. The vignettes were designed to investigate two important factors that teachers may perceive as important predictors of student success in engineering studies: student academic abilities and social background. For example, vignettes V1 and V3 represent two fictitious students who share similar characteristics such as gender, social class status, and high interests in engineering, yet differ in academic abilities, as indicated by their GPAs and course grades. Using these students' profiles, teachers were asked to advise these students about pre-engineering course enrollment, and make predictions about these students' success in advanced engineering studies and future careers. Differences in teachers' advising and predictions of these students' success can be attributed to their perceptions of the students' academic abilities. Similarly, Vignettes V2 and V4 highlight the differences in students' social backgrounds (one girl's father is a construction worker, while the other girl's father is an electrical engineer) after controlling for gender, academic abilities, and technical interests. Thus, differences in teachers' advising and predictions of these students' success are likely to be attributed to teachers' perceptions of social background as an important factor of student success in engineering studies.

Analyses

We performed three levels of analyses. First, we observed the frequency distribution for each of the 71 items. Second, we examined categories of teacher beliefs and practices generated by the research team and conducted a reliability analysis. Using the results generated by a reliability analysis, we described seven summary constructs representing different dimensions of teacher beliefs about engineering education. Third, we generated a descriptive analysis of the vignettes to gain an understanding about the factors used by teachers to advise students and predict student success in engineering studies and careers.

Results

Frequency Distributions

Prior to conducting the empirical analysis, we computed proportions of teachers who reported that they often or almost always carried out the following activities (with construct labels from A through G): A) using student academic abilities to inform their instructions; B) integrating of students' background knowledge during instruction; F) integrating math, science, technology, and engineering in the classroom; G) receiving support from their school for engineering studies. We also examined the proportions of teachers who agreed or strongly agreed with the following general principles: C) there is a connection between in-school and out-of-school learning experiences; D) students' academic preparation can influence their careers in engineering; E) students' backgrounds influence their readiness for careers in engineering.

Table 1 shows the frequency distributions for the various items. Here, we present the proportions of teachers who *agreed or strongly agreed* on factors that influence student preparation for engineering. It is interesting to note that our descriptive analysis shows that more than 75% of respondents *agreed* or *strongly agreed* that engineering preparation takes place in multiple contexts. Teachers believe that to ensure future success in engineering students must have high academic (i.e., college preparatory course) achievement (48.6%), enroll in technical education courses (55.6%), and have work experience in a technical field (32.6%).

Table 1: Percentages of teachers who reported that they *agreed or strongly agreed* to statements concerning engineering preparation.

Item	Frequency n	%
C. Connection Between In-school and Out-of-school Learning		
1. Learning takes place when a student participates in activities that take place in his/her household	112	77.8
2. Learning takes place when a student participates in activities guided by other adults in the community (e.g., church or temple, girl/boy scouts, non-profit organization, etc.)	113	78.5
3. Students' classroom learning transfers to out-of school settings	90	62.5
4. Student learning in out-of-school settings informs my classroom instruction	52	36.1
5. I make explicit connections between what is taught in the classroom and my students' experiences in out-of-school settings	83	57.6
6. Students make their own connections between their out-of-school experiences and classroom activities	51	35.4
D. Academic Preparation and Careers in Engineering		
7. To be an engineer a student must have high overall academic achievement	70	48.6
8. To be an engineer a student must get A's and B's in math, science, and technology courses	65	45.1
9. To be an engineer a student must perform above average in all of the honors and advanced placement (AP) courses in math and science	13	9.0
10. The student with a higher GPA is more likely to pursue a career in engineering than a student with a lower GPA	57	39.6
11. The student with higher ACT or SAT scores is more likely to pursue a career in engineering than a student with lower ACTs or SATs	46	31.9
12. Any student seriously interested in a career in engineering should enroll in pre-engineering courses in high school (such as Project Lead The Way)	70	48.6
13. Any student seriously interested in a career in engineering should enroll in some career and technical educational courses	80	55.6
14. The student who is good in math and science is the best candidate to become an engineer.	56	38.9
E. Social Background and Careers in Engineering		
15. The student whose parent is an engineer is most likely to pursue engineering	19	13.2
16. The student who has a close relative that is an engineer is most likely to pursue engineering	18	12.5

17. The student who knows someone that is an engineer is most likely to pursue engineering	23	16.0
18. The student who is serious about becoming an engineer should have work experience in a technical field	47	32.6
19. All other things being equal, students with well-to-do parents are most likely to pursue engineering	26	18.1
20. All other things being equal, male students are more likely to become engineers than female students	33	22.9
21. All other things being equal, White students are more likely to pursue engineering than other students	19	13.2
22. All other things being equal, Asian students are more likely to pursue engineering than other students	15	10.4

With regards to teacher instructional practices, a large proportion of the respondents reported that they *often or almost always* rely on tests to measure student learning (77.8%) and use student interests to engage student learning (68.1%). While 73.6% of the respondents reported using technology in their instructional activities, on average only 35% reported that they often or almost always integrate math, science, technology, and engineering concepts in the classroom. Concepts aside, most (> 70%) report using some form of technology during instruction. The small degree of conceptual integration of STEM in the classroom may be attributed to the modest support available in the school settings (see Table 2).

Table 2: Percentages of teachers who reported that they *often or almost always* use the following instructional practices in the classroom.

Item	Frequency n	%
A. Using Student Academic Performance to Inform Instruction		
23. I use students' prior achievement on statewide standardized tests to structure activities in my classroom	10	6.9
24. I give tests to assess how well students are performing in my class	112	77.8
25. I modify my lessons based on student performance on the assessments administered in my class	97	67.4
26. My lessons are informed by students' academic performance in other classes	17	11.8
27. I repeat lessons when students do not show mastery of the concept taught	53	36.8
28. I modify instructional activities based on students' enthusiasm about the topic being taught	48	33.3
29. I rely on each student's studying habits to judge how well he/she performs in my class	15	10.4
30. I use each student's attendance to determine how well he/she performs in my class	20	13.9
B. Using Social Background to Inform Instruction		
31. I know my students' goals and aspirations	95	66.0
32. I use students' interests to engage them in learning	98	68.1

33. My lessons are informed by my knowledge of my students' hobbies	42	29.2
34. I integrate students' work experiences to the learning activities in the classroom	44	30.6
35. I integrate students' home language in the lessons	14	9.7
36. I integrate students' cultural background in the lessons	18	12.5
37. I take into account students' ethnicity when structuring activities	22	15.3
F. Integrating Science, Technology, Engineering, and Technology (STEM)		
38. The math content being taught in my courses is explicitly connected to engineering	48	33.3
39. The science content being taught in my courses is explicitly connected to engineering	52	36.1
40. The technology courses being taught in my courses are explicitly connected to engineering	50	34.7
41. I collaborate with other teachers at my school to develop interdisciplinary lessons that focus on engineering	14	9.7
42. I integrate technology standards when teaching math	49	34.0
43. I integrate technology standards when teaching science	66	45.8
44. I integrate technology in my classroom instructional activities	106	73.6
G. Having Support for Engineering Studies		
45. My school provides Career Day workshops for all students	35	24.3
46. My school provides information to students who have questions about engineering	71	49.3
47. Teachers and guidance counselors work together to provide resources for students interested in engineering	55	38.2
48. My school has an internship program for students interested in engineering	24	16.7
49. My school works with parents to provide support for students interested in engineering	32	22.2
50. My school provides professional development for teaching engineering	25	17.4
51. We have a pre-engineering curriculum at my school	62	43.1
52. We have an engineering apprenticeship program at my school	22	15.3

Construct Reliability for the EEBIE-T Survey

We engaged in reliability analysis with each of the seven constructs, based on the presumption that the groupings generated by the research team were essentially sound, though any given item might or might not contribute to an optimal estimate of construct reliability. Even when minimal improvements were possible by dropping an item, we often did so in order to obtain a shorter survey for future survey administrations.

Even though the items were originally grouped to describe the targeted constructs, reliability analyses were generated to provide evidence of and to improve on how these items represent the various constructs. Table 3 below provides a summary for the number of items originally used to make up each construct, and the items that were retained after the reliability analysis.

Table 3: Summary of the development for various constructs.

A: Students' Academic Abilities

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G, H	.635	Remove H	Increase α to .649
A, B, C, D, E, F, G	.649	Remove B	Increase α to .659
A, C, D, E, F, G	.659	Remove G	Increase α to .696
A, C, D, E, F	.696	None	Final Scale

B: Students' Backgrounds and Interests

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G, H	.828	None	Final Scale

C: Beliefs and Knowledge About Student Out-of-School Activities

Items	Alpha	Action	Rationale
A, B, C, D, E, F	.772	Remove F	Increase α to .779
A, B, C, D, E	.779	None	Final Scale

D: Careers in Engineering: Academic Success

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G, H	.732	Remove F	Increase α to .762
A, B, C, D, E, G, H	.762	Remove G	Increase α to .827
A, B, C, D, E, H	.827	None	Final Scale

E: Careers in Engineering: Social Network/Background

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G, H, H_A	.787	Remove D	Increase α to .796
A, B, C, E, F, G, H, H_A	.796	None	Final Scale

F: Teaching for Engineering: Academic Courses

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G	.868	Remove F	Increase α to .877
A, B, C, D, E, G	.877	Remove G	Increase α to .884
A, B, C, D, E	.884	Remove E	Increase α to .901
A, B, C, D	.901	Remove D	Increase α to .922
A, B, C	.922	None	Final Scale

G: Connections to Engineering: Environmental and Structural Support

Items	Alpha	Action	Rationale
A, B, C, D, E, F, G, H	.781	Remove G	Increase α to .783
A, B, C, D, E, F, H	.783	None	Final Scale

Reliability analysis for the EEBIE-T that was conducted on each scale reduced the survey to 41 items distributed over 7 constructs. The final constructs and reliability analysis are summarized in Table 4. The titles and verbal interpretation that are shown for each construct are inferred and did not appear anywhere on the survey, but are given to help the reader understand the overall meaning conveyed across the range of items given. In addition to the title, we show the total number of items remaining for each construct after dropping items out, as recommended by reliability analysis and our own determination. This is followed by whether it was a 5-point or 7-point scale. We then summarize the findings from the survey administration (N = 144). First we provide the mean response score for each construct using that scale (where closer to the midpoint of each scale indicates a lack of a skewed construct, which is desirable). Then we show the value of Cronbach's alpha ($0 < \alpha < 1$) as the reliability measure for that construct based on all teacher responses.

Table 4: Summary of construct reliability for EEBEI-T survey administration (N = 144).

Construct Title and Interpretation	No. Items	Scale	Mean	**α**
A. **Influences on Instruction: Students' Academic Abilities**. My lessons are influenced by students' academic performance.	5	5	3.08	.70
B. **Influences on Instruction: Students' Backgrounds and Interests.** I integrate students' interests and cultural backgrounds into classroom activities.	7	5	3.00	.83
C. **Beliefs and Knowledge about Student Out-of-School Activities.** Students' science / math / technical learning takes place in the home and community.	5	7	5.69	.78
D. **Careers in Engineering: Academic Achievement.** To be an engineer a student must have high academic achievement in math, science and technology courses.	6	7	4.88	.83
E. **Careers in Engineering: Social Network/Background.** The student whose parent is an engineer, male, and either white or Asian, is most likely to pursue engineering.	7	7	4.88	.82
F. **Teaching for Engineering: Academic Courses.** The science and math content taught in my courses is explicitly connected to engineering.	3	5	3.12	.92
G. **Environmental and Structural Support.** My school provides resources for students interested in engineering (e.g., internships, career day, professional development opportunities).	7	5	2.71	.78

As should be clear from the summary in Table 4, the reliability analysis and the construct mean values suggest that the EEBIE-T is a well-designed instrument. First, the mean scores of each construct are near the center value for each scale. Second, the estimated values for Cronbach's alpha fall between .70 and .92, which is considered "acceptable" in Social Science research.

With construct reliability established, we can now interpret the responses from teachers for these seven aspects of engineering preparation. Results from construct A show that, on average, teachers believe that their lessons are sometimes influenced by students' academic performance. In construct B teachers generally believe that they sometimes integrate students' interests and cultural backgrounds into classroom activities. Construct C results reveal that teachers agree fairly strongly that students' science, math, and technical learning takes place in the home and in the community. Findings from construct D indicate that teachers generally believe that to be an engineer a student must show high academic achievement in their math, science and technology courses. Overall, teachers somewhat agree that a student is most likely to pursue engineering if a student's parent is an engineer, and if the student is male and either white or Asian (Construct E). Construct F responses indicate that teachers, on average, believe they sometimes explicitly connect the science and math content taught in their courses to engineering activities and ideas. Reponses to construct G reveal that, on average, teachers believe that their schools tend not to provide resources for students interested in engineering (e.g., internships, career day, professional development opportunities).

Vignettes as Measures of Teachers' Decision Making

The vignettes were intended to reveal elements of teachers' decision-making for advising fictional students toward or away from engineering classes, and to elicit their expectations for student success in advanced engineering studies and careers. The vignettes were designed to allow us to make comparisons about factors that influence teachers' recommendations. While each vignette presented a moderately rich portrait and provided numerous attributes describing student personal characteristics, interests and academic abilities, we focus on two major factors that are likely to influence teachers' perceptions of engineering preparation: student academic performance and student social background. As Table 5 shows, we designed two sets of vignettes that closely examine these two factors. The first pair of vignettes (V1 and V3) describes two students with similar background but differs in academic performance (course grade and GPA). The second pair of vignettes (V2 and V4) depicts two students of similar academic abilities but vary in social background. In Table 5, we provide a summary of the student profiles described in the four vignettes.

Table 5: Comparative structure of the vignettes.

	V1	V3
Compares Academic Performance	Gender: Male Grade: 10th Background: low SES GPA: 3.85 Interests: To enroll in *Principles of*	Gender: Male Grade: 10th Background: low SES GPA: 1.35 Interests: Assembling body kits on

	Engineering course and to attend college.	foreign cars and to attend college.
	V2	V4
Compares Social Background	Gender: Female Grade: 11th Background: high SES GPA: 3.45 Interests: To enroll in *Digital Electronics* course and thinks her father's work as an engineer is "cool."	Gender: Female Grade: 11th Background: low SES GPA: 3.45 Interests: To enroll in *Digital Electronics* course and uninterested in her parents' blue collar jobs.

For each vignette, we asked teachers to do the following: (a) recommend whether a student should enroll in a pre-engineering course the following year; (b) specify the criteria used to make the recommendation (e.g., prior academic performance, overall GPA, gender, age, social economic status, family background, etc.); (c) and predict the student's success as a working engineer.

Our analysis of the responses to the vignettes demonstrates that respondents did not answer all vignettes the same way, and that elements that differ between the students had some effect on teacher response. Figure 1 shows that, across all four vignettes, a large proportion of the teachers supported student enrollment in pre-engineering courses (> 70%).

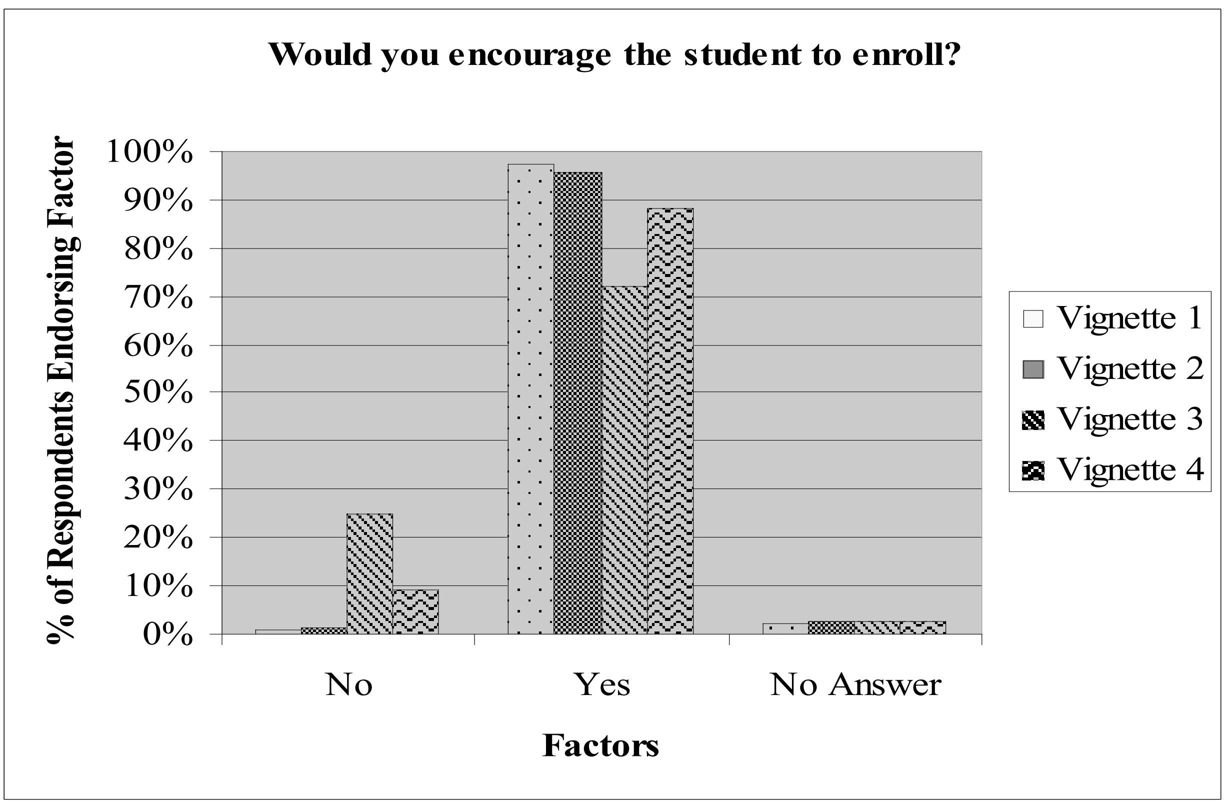

Figure 1. Teachers' recommendations for student enrollment in pre-engineering courses.

This is notable when it is compared to the overall proportion of teachers (< 24%) who did not advise the student to enroll in a pre-engineering course based on the student's academic preparation, social background, grade, gender, or interests.

We also find there is variation in teachers' endorsements of student enrollment in pre-engineering courses. While student socioeconomic status (SES) was never a factor when considering student enrollment in these courses (as shown in Figure 2, below) family background was somewhat endorsed, particularly for V2, where 20% of teachers reported using it in their decision. However, student social background appears to be much less important to the teachers in this sample than the student academic preparation (academic history and GPA). While academic preparation is often endorsed, it differs dramatically from student to student. Below we explore the various criteria teachers used to make their recommendations for student enrollment in pre-engineering studies.

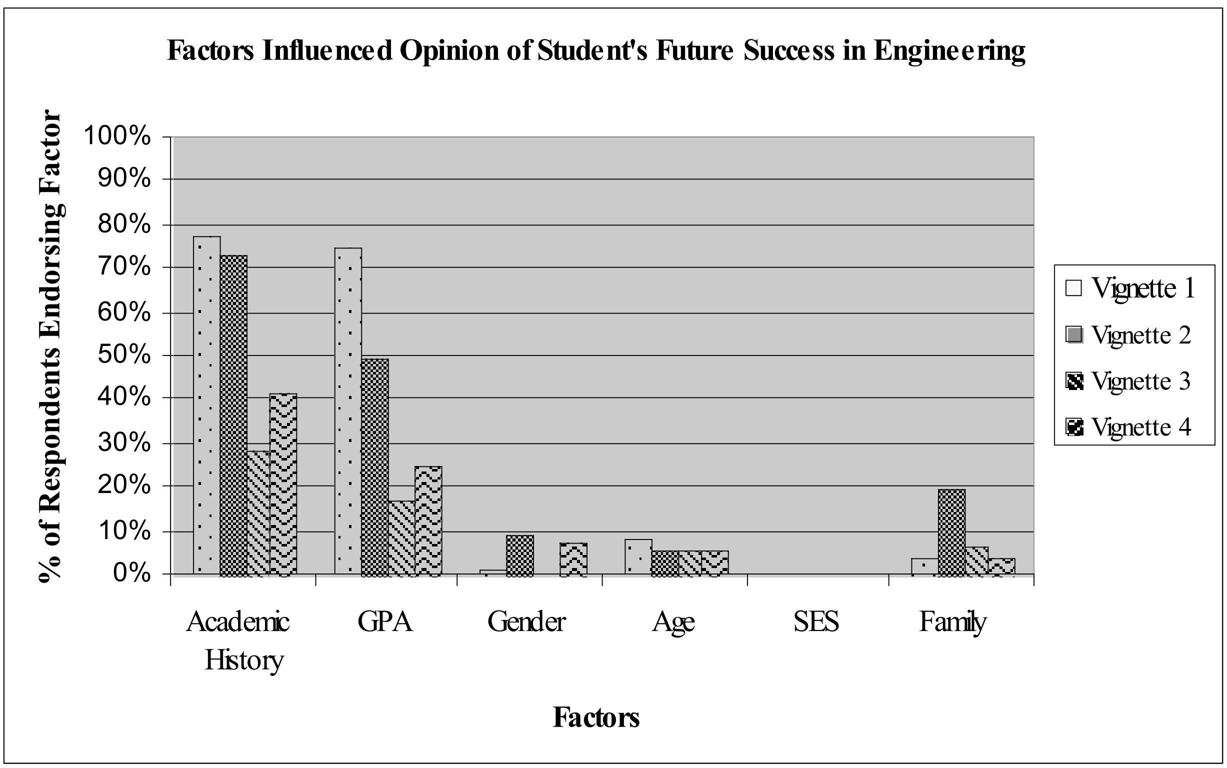

Figure 2. Teachers' perceptions of factors that influence pre-engineering studies.

The comparison between V1 and V3 shows low versus high course grades in math and science and high GPA overall, controlling for family income, student gender (both male), lack of pre-engineering experience, and parental working class (in one a single mom works two blue collar jobs, while the other has a dad working in an auto shop). For the high GPA student (V1), a large percentage of teachers reported using course grades (78%) and GPA (75%) to recommend future success in engineering. For the low achieving student (V3), academic performance was seldom used to endorse a career in engineering. This suggests a potentially important effect where STEM teachers may be predisposed to support enrollment in pre-engineering courses, and will use prior academic performance to justify that decision *for higher achieving students*, but will not use academic performance to justify their decision to support enrollment for lower achieving students. This implies that teachers are more willing to make decisions about students' engineering studies when they have adequate data (course level and GPA) to support their decision. Thus, providing a range of information about students' preparation for engineering appears to be critical to gain teachers' endorsement.

The comparison between V2 and V4 highlight the differences in student backgrounds with one student (V2) from a higher socioeconomic background whose parents are engineers while another student (V4) from a lower socioeconomic background. Both are female with identical GPA's and grade level. For the student with the more privileged background (V2), 73% of the teachers reported using course grade and 50% indicated using overall GPA as criteria to recommend future engineering studies. For the student with less advantaged background (V4), only 42% of the teachers reported using course grade and 25% using GPA as criteria to promote future engineering studies. A much smaller proportion of teachers reported using course grades and GPA as factors to recommend V4 enrolling in engineering studies. This is a striking effect that suggests socio-economic factors of a students' family may influence the decision making process of teachers with regard to engineering studies.

We conducted secondary analysis of the comparisons between V1 and V2: two students who both have high GPA and good grades in math and science, but vary in family background. The girl (V2) has a father in engineering, while the boy (V1) is being raised by a single mom working double shifts. The girl's family background appeared to provide teachers added impetus to recommend pursuit of engineering (20% of teachers factored this in for the girl vs. 5% for the boy). Knowledge of history of engineering in the family appears to be an important component in teacher's endorsements. However, the high GPA was weighted less heavily for the girl (50%) than for the boy (75%).

Lastly, V3 versus V4 permit us to compare the effect of the students' prior experiences in pre-engineering courses. The girl (V4) has one course (*Introduction to Engineering Design*) with a B grade, but otherwise has mid-level to poor grades (D in pre-calculus, B in economic, C's otherwise). The boy (V3) has no pre-engineering experience and poor grades, with no advanced math or science. Prior experience in the pre-engineering program appears to make the girl's academic performance a stronger factor for teachers in recommending engineering than for the boy. Gender did not appear to be a factor in teachers' decisions.

Overall, academic factors weighed heavily with teachers, though a parent as an engineer also contributed to teachers endorsing engineering pursuits. Teachers are more likely to support students with higher GPA for engineering studies. As shown above in Figure 2, when asked explicitly, teachers reported that they did not use social background (SES) as a factor when making their decisions about pre-engineering enrollment in any of the four vignettes. However, in a more tacit exploration of teacher decision making, comparisons between students with varying social background (V2 versus V4) but comparable academic performance histories suggest that teachers *implicitly* accounted for student's social backgrounds when forming opinions about student's future success in engineering. Taken together, data obtained from the vignettes reveal that both academic factors and information about student background play an important role in teachers' perceptions about engineering preparation.

When asked to make predictions about student's success in a future career as an engineer, at least 49% of the respondents reported that they could not predict given the information provided in the vignettes (Figure 3). The remaining proportion show variation in their prediction of student success in engineering careers based on student academic preparation, social background, and interests. Teachers predicted that students with higher academic preparation (V1) and parents who are engineers (V2) "will do well in engineering." In contrast, students with lower academic preparation (V3) and from lower social backgrounds (V4) "will struggle in engineering." While academic preparation is understandably an important factor that teachers used to make predictions about future success in engineering, we cannot overlook the role that social backgrounds play in teachers' decisions. This is most evident in the comparisons between V2 (higher SES) and V4 (lower SES) where both students differ in social background but share similar characteristics such as academic preparation, gender, grade level. However, 50% of the teachers predicted that V2 "will do well in engineering" compared to 13% for V4. Finally, very few teachers endorsed extreme positive (the rapid promotion) or negative (dead-end technical position) options for describing future engineering outcomes. We suspect is this is the case because that they may not have been able to accurately predict what type of person would fall into either of these two categories, while 'doing well' or 'struggling' would be easier to categorize (see Figure 3).

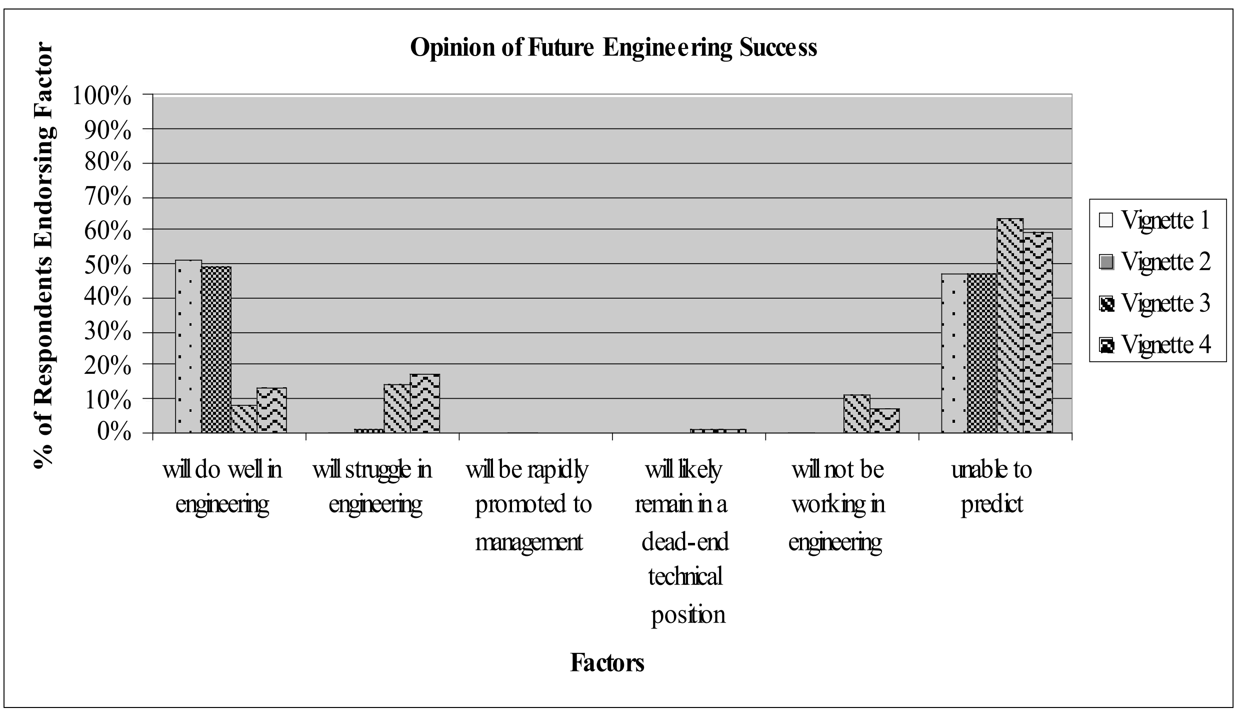

Figure 3. Teachers' predictions of student success in engineering careers.

Discussion

Instructional practice and teacher decision-making processes are influenced by teachers' beliefs and expectations about student learning and about teachers' own instructional practices. To affect changes in engineering educational practices, knowledge of these beliefs and expectations need to be rigorously documented. This study, then, sought to develop a statistically reliable survey instrument that documents teachers' beliefs and expectations about high school pre-engineering instruction and preparation for students' future success in college engineering programs and careers in engineering. The EEBEI-T instrument was given to 144 high school STEM teachers located in a moderately large urban city in the Midwestern US. Results show the instrument to contain highly reliable constructs ($\alpha \geq .70$), with sample means falling midway on the Likert scales. Consequently, we can interpret the substantive findings with some degree of assurance that the quantitative patterns in the data are robust. In terms of instructional practices, teachers report using students' interests, cultural and family backgrounds, and student assessment performance to guide their instruction. A minority of teachers reported that they adequately integrate math and science concepts with engineering activities and concepts.

With regard to engineering preparation, teachers agreed that it takes place in multiple contexts, including academic, technical education, as well as home, community and workplace settings. Teachers generally believe that to become an engineer a student must show high academic achievement in their math, science and technology courses. Teachers also believe that having a parent as an engineer increases a student's likelihood of becoming one, as does being male and either white or Asian. However, socio-economic status was not reported as an important consideration by the teachers when determining student preparation using the Likert scale items.

We also elicited information from teachers about their beliefs in a more situated manner, by presenting them with vignettes of students who were seeking advice about enrolling in pre-engineering courses and pursuing future careers in engineering. The vignettes asked teachers directly about factors that influenced their decisions, such as gender, age, student socioeconomic status (SES), family background, engineering profession of a parent, academic history and overall GPA. But there was also a more tacit approach taken in the vignettes, where comparisons were set up in the design between student profiles. This proved enlightening, since some of the factors that were implicitly varied appeared to influence teacher evaluations and recommendations even though they were excluded as factors when presented explicitly to teachers. Thus, when explicitly asked, socioeconomic status (SES) was never a factor in teachers' decisions, family background was somewhat relied on, ad academic performance was very frequently cited. However, when comparative analyses were made across the vignettes, academic performance was applied unevenly across the fictional students, strongly applied to those students with privileged family circumstances, but applied much less frequently for a student with a less advantaged background. While teachers did not report social background as a factor that influenced their decisions when explicitly asked, comparisons between students with varying social background (e.g., V2 versus V4) but comparable academic performance histories suggest that it did influence teachers' endorsements for pre-engineering enrollment and for predicting a student's future success in the engineering profession. Based on this, we found that the vignettes provided an important complementary set of findings about the decision-making processes used by teachers.

In any major educational reform effort, teachers are critical to ensuring success[19]. However, teachers may operate with beliefs about learning and instruction that are incompatible with central principles of the reform effort[20,21]. The pool of engineers in the United States is neither large enough nor diverse enough to meet the needs of a growing, high-tech economy[22]. Yet the "talent pool" among many sectors of the population goes largely untapped[23]. As Legand Burge, dean of the College of Engineering, Architecture and Physical Sciences at Tuskegee University, one of the nation's premiere Black colleges, says, "there needs to be more of a national commitment to improve the teaching of technology" in high school level to promote engineering[23]. This means that reform of engineering education must not only address content area knowledge among K-12 teachers, but teachers' attitudes and expectations about those interested in pursuing engineering studies and technical careers. As the research base grows, and we develop a better picture of the beliefs and expectations of K-12 STEM teachers, we will be better able to design teacher educational and professional development programs that promote views more favorable to early engineering learners.

This study, along with others[17] has contributed to this developing knowledge base. Yet we also want to acknowledge some of the limitations of this current research. Our sample was specific to high school STEM teachers in the Midwestern US. A national sample will be of great value to see if the patterns hold true more broadly. It will also be valuable to employ the EEBEI to other populations in the engineering pipeline. We currently have plans to administer version of this instrument to high school guidance counselors, who play a large role in students' course enrollment and post-secondary decisions, as well as to college and university level instructors. Finally, we imagine that this survey can be used as more than an instrument of teachers' static beliefs, but one that can be used to measure changes in beliefs that may be due to training programs or other professional development experiences. Currently we have efforts in place to conduct such a longitudinal study that we hope to report on in the near future. Engineering excellence in the US serves as one of the primary vehicles for technological innovation, economic prosperity, national security, and advancements in public health. By establishing a reliable instrument that measures teachers' beliefs and expectations about high school pre-engineering instruction and preparation for students' future success engineering, we hope to contribute to the wide scale efforts currently in place to expand and improve engineering education and foster a more technologically advanced society that contributes to the greater good.

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