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How Professional Development in Project Lead the Way Changes High School STEM Teachers' Beliefs about Engineering Education

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Abstract

This quasi-experimental study measured the impact of Project Lead the Way (PLTW) instruction and professional development training on the views and expectations regarding engineering learning, instruction and career success of nascent pre-college engineering teachers. PLTW teachers' initial and changing views were compared to the views exhibited by a matching group of high school STEM teachers. The primary instrument was the Engineering Beliefs and Expectation Instruments for Teachers (EEBEI-T), which included Likert scale items, contextualized judgments about fictional student vignettes, and demographic items. Teachers' baseline survey responses, on average, revealed the importance of academic achievement on teachers' decision making about who should enroll in future engineering classes and their predictions of who would be most likely to succeed in an engineering career. When making implicit comparisons between students who differed by SES, teachers generally favored enrollment and predicted more career success of high SES students. SES was excluded as a factor in the judgments of all participating teachers when explicitly probed, however. Preexisting group differences showed that budding PLTW teachers reported on STEM integration in their classes with greater frequency than control teachers, while control teachers agreed more strongly about the pre-requisite role of high scholastic achievement for engineering studies. Finally, an analysis of teachers' changing views indicated that nascent PLTW teachers increased their reporting of effective STEM integration over time, above and beyond pre-existing group differences and re-testing effects. In light of these data we explore the challenges of implementing effective STEM integration in high school classrooms, examine issues of attracting underrepresented students to engineering, and discuss some of the inherent tensions of engineering education at the K-12 level.

Keywords: Diversity in engineering, K-12 engineering education, STEM Integration, Teacher beliefs.

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As United States high schools respond to calls for improving student learning in science, math, technology and precollege engineering (NRC, 2007) and confront the increasing availability of funding opportunities such as Race to the Top, greater numbers of K-12 educators are participating in professional development activities for Science, Technology, Engineering and Mathematics (STEM) (science, technology, engineering, and mathematics) education. Consequently, there is a growing need to understand K-12 STEM teachers' knowledge and beliefs, effectiveness and instructional decision making (Fink, Ambrose, & Wheeler, 2005). Education research shows that instructional practice and teacher decision making are influenced by teachers' beliefs about learning and instruction (Borko, Livingston, & Shavelson, 1990; Brophy & Good, 1974; Grossman, 1990; Nathan & Koedinger, 2000; Rosenthal & Jacobson, 1968). Furthermore, the educational experience for students is dependent on the quality and effectiveness of teachers, more than perhaps any other single alterable factor (Leinhardt & Greeno, 1986; Nye, Konstantopoulos, & Hedges, 2004; Rowan, 2004). For example, teachers' views have serious implications for the perceived place and purpose of engineering in the K-12 curriculum, as noted in a recent report from the National Academy of Engineering (Custer & Daugherty, 2009). Furthermore, as professional development programs in pre-college engineering proliferate, there is additional need to understand the nature of changes we can expect to see in teachers' beliefs and expectations about engineering instruction and learning as teachers learn more about engineering and ways to teach it.

There have been recent studies on teacher knowledge, beliefs, and instructional practices for engineering education. Cunningham (2009) showed changes in elementary teachers' reports about their content knowledge, pedagogy, and student engagement as a result of participating in the Engineering is Elementary (EiE) professional development workshops. Student outcome measures showed greater gains associated with the EiE teacher training.

Yasar and colleagues (2006) surveyed K-12 teachers' knowledge and perceptions of engineers and engineering practice. The authors argue that understanding teachers' views in this area is a necessary step toward developing long-range plans to better integrate technology and design into K-12 education. Shulman (2005), directing research of the Carnegie Foundation for the Advancement of Teaching, documented how universities prepare students for professional practice in areas of law, nursing, the clergy, and engineering. The "signature pedagogy" for engineering is shown to demonstrate "a lovely juxtaposition between the formal requirements entailed in learning math and science and the creative challenges that accompany 'messing with the world'" (p. 11). Still, the editors of *Journal of Engineering Education* rightly point out, there is still little known about the "engineering teaching culture" (Steering Committee of the National Engineering Education Research Colloquies, 2006).

To address this growing area of interest and importance, we set out to examine already-practicing teachers' beliefs and expectations about engineering instruction and student learning as it occurs at the high school level, and document how these views change as teachers become newly trained to teach an engineering education curriculum. We examined teachers' changing beliefs in the context of their initial experiences teaching courses from the Project Lead the Way (PLTW) program. Although some selection bias is inherent in a study of this nature (we are not currently at liberty to assign who will and will not teach PLTW), causal inferences are supported by quasi-experimental design that examines changes in teachers' views before and after their first PLTW course above and beyond those changes exhibited by a matching group of STEM teachers who did not participate in the training or teaching of a PLTW course.

Measuring STEM Teachers' Beliefs About Engineering Education

Previous research (Nathan, Tran, Atwood, Prevost, & Phelps, 2010) has shown the Engineering Education Beliefs and Expectations Instrument for Teachers (EEBEI-T; pronounced "eebee tee") to be a valuable instrument for measuring teachers' views as they relate directly to precollege engineering education, preparation for future studies in engineering, and expectations for success in engineering careers. The EEBEI-T was originally given to 143 high school STEM teachers located in a moderately large urban city in the midwestern United States. Part one of the instrument included a set of Likert scale items that contained seven highly reliable constructs ($\alpha \geq .70$). Reliability of the constructs was replicated with a second administration to a national sample of STEM teachers ($N = 82$).

In findings about STEM instruction, most teachers report using students' interests, cultural and family backgrounds, and prior academic performance to guide their teaching practices. A minority of teachers reported that they adequately integrate math and science concepts with engineering activities and concepts. With regard to engineering preparation, teachers generally agreed that it takes place in multiple contexts, including academic and technical education courses, as well as at home, and in community and workplace settings. Teachers generally believed that to become an engineer students must show high academic achievement in their science, math, and technology courses. Teachers also believed, on average, 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, student socioeconomic status (SES) was not reported as an important consideration by the teachers when determining student preparation using the Likert scale items.

Prior results also showed the EEBIE-T to be sensitive to group differences between teachers who focused primarily on engineering education within career and technical education programs and those STEM teachers in the sample primarily focused on instruction in college preparatory math and science. Statistically significant differences ($p < .05$)

between these two groups of STEM teachers were identified in three areas. First, math and science teachers as a group were less likely to identify sources of support for engineering in their schools than engineering teachers. Second, on average, math and science teachers more strongly supported the view that an engineer needs to show high levels of academic achievement in science, math, and technology. Third, engineering teachers collectively were far more likely to contend that their classroom instruction effectively integrates engineering activities with concepts from math and science.

Content validity (Cronbach, 1971) of the instrument, sometimes also referred to as "face validity," was also established. First, the survey corroborated the expectation that current and prospective engineering teachers would be more aware of the engineering resources offered and were more likely to be in schools that offer such resources. Second, as expected, the survey found that teachers of academically oriented science and math courses that typically serve a college preparatory function, rather than providing technical skills, will regard excellence in academic performance as paramount to success in engineering.

In part two of the instrument, teachers read vignettes that profiled four fictional high school students with differing academic, gender, and socioeconomic descriptions in order to further reveal teachers' views during contextualized advising and decision making tasks. Analyses of teachers' responses compared across the vignettes showed that teachers relied a great deal on a student's prior academic performance when deciding on whether to endorse the students for enrollment in engineering courses, and when predicting the student's likelihood of success in a future engineering career. Teachers' decisions were also apparently influenced by family SES of the student. Specifically, teachers tended to support enrollment in engineering classes and predict higher rates of career success for students from more privileged family circumstances. Teachers were not consciously aware of these influences, however, as indicated by their responses to other survey questions.

Having demonstrated the reliability, validity, and utility of the EEBEI-T, the next logical step is to use it to measure changes in teachers' views as a result of their professional development and teaching experiences in engineering education. This would provide insights about the impact that these new teaching experiences can have on teachers' views. Such findings contribute to our understanding of the nature of high school engineering instruction and teacher change during a critical stage of the engineering pathway.

Precollege Engineering Education: The PLTW Curriculum and Teacher Training Program

We chose to examine teacher belief change in the context of a specific, well-regarded engineering program, Project Lead the Way (PLTW). PLTW is one of the most widely used precollege engineering curricula in the United States. The program has been adopted by more than 2,700 schools (2000 high schools and 700 middle schools; Katehi, Pearson, & Feder, 2009), and is present in all 50 states (Walcerz, 2007). PLTW was singled out in *Rising Above the Gathering Storm* (NRC, 2007) as a model curriculum for providing the kind of rigorous K-12 materials needed to improve math and science learning and increase America's technological talent pool. Thus, findings based on PLTW have far-reaching implications.

PLTW is designed to integrate engineering, science, math, and technology into the students' academic program of study at the middle and high school levels. The high school program *Pathway to Engineering*™ offers seven high school courses 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). These courses can be used for credit at accredited colleges and universities. In addition, there is an engineering research capstone course, Engineering Design & Development (PLTW, 2004).

As a precondition to teaching any one of the PLTW courses, teachers must attend an extensive professional development program, including training provided by the PLTW network of affiliate colleges and universities. This training aims to make teachers proficient in content knowledge and project- and problem-based instruction. National affiliates offer graduate credit for teachers.

A recent international review of research on professional learning for educators by Linda Darling-Hammond and colleagues (2009) reports that strategically designed, intensive, and sustained professional learning can have a powerful influence on teacher skills and knowledge, and ultimately lead to improvements in student learning. Prevost and colleagues (2009) examined the PLTW teacher professional development training documents, training activities, teacher projects, and teacher self-assessment and self-reflection items for the PLTW foundations courses. The authors described the trainings as academically intense programs tailored to the respective student course, localized to a two-week summer course. The focus on the PLTW summer training institute is for teachers to gain mastery of the curriculum content they will teach, including familiarity with the design and measurement tools typically used by engineers such as drafting, CAD, and tools for physical and virtual dimensioning (Introduction to Engineering Design); knowledge of simple machines, thermodynamics, free body diagrams, kinematics, and ballistic devices (Principles of Engineering); and coverage of the laws of physics and principles of engineering design as they apply to analog and digital electronics, such as Ohm's law, truth tables, Karnaugh maps, Boolean algebra, use of the computer program MultiSims, the basic electronic robot Basic Stamp, combinational and sequential logic design, and how to create and troubleshoot breadboard circuits, including mastering the use of a logic

probe and multimeter (Digital Electronics). Analysis of the teacher materials show it is rich with math and science concepts that were often explicitly integrated into the engineering activities, particularly for later courses in the curriculum sequence. Little in that analysis, however, was revealed about the impact these training experiences had on teachers' beliefs, knowledge, and instructional practices.

Research Goals

Several research goals drove this investigation. First, in an effort to better understand the "engineering teaching culture" at the high school level, we set out to measure precollege STEM teachers' beliefs about engineering education. Specifically, we examined teachers' baseline views in areas such as how they prepare students, which student factors influence their instruction, who teachers thought should have access to engineering courses, and which student traits teachers believed predicted a successful engineer. Since a portion of the teachers in our sample would subsequently participate in a formal professional development program for engineering education, as a second goal we wanted to assess preexisting differences that may exist between STEM teachers that went on to teach engineering courses and those that did not.

Third, we set out to document the changes in beliefs that arose as a consequence of becoming a newly minted precollege engineering teacher. As noted, we chose to do this in the context of a specific, representative program, PLTW, because of its wide use nationally and its reputation for achieving rigor in STEM education (NRC, 2007). To obtain a more realistic sense of the impact of the intervention, we measured the combined impact on teachers' beliefs of the PLTW professional development training and the initial PLTW teaching experience. We re-administered the beliefs survey to STEM teachers who did and who did not participate in the PLTW training program and go on to actually teach a PLTW course. Together this approach led to a 2 factor (time 1 vs. time 2) by 2 factor (summer institute, SI vs. control, CO) *quasi-experimental design* (Shadish, Cook, & Campbell, 2002) that examined changes in pre- and postintervention survey responses for SI teachers above and beyond changes exhibited by those CO teachers who did not elect to train and teach a PLTW course within the time period of the study. Finally, we documented teachers' decision making about specific (fictional) students as portrayed in student vignettes.

Method

Participants in the initial administration of the EEBEI-T survey were high school science, mathematics, and technical education teachers (N = 182; see Table 1 for the population demographics, where column Ns differ from the total sample size because some participants opted to not respond to some demographics items). Teachers were recruited by email through state departments of instruction and the PLTW affiliate colleges. Most respondents were white (95.9%) and male (59.8%). None of the teachers had taught PLTW at the time of the first survey administration or taken part in the PLTW teacher summer institute training. During summer 2008 some of the teachers (N = 82) attended a mandatory PLTW summer institute (SI) and became initially certified to teach PLTW engineering courses. The remaining control (CO) teachers (N = 100) provided control for time and repeated exposure to the survey items.

Table 1
Teacher Demographics Overall and By Comparison Groups

	Overall	Control	SI
No. Years Teaching	N = 174	N = 96	N = 78
0–3	15.52%	11.46%	20.51%
4–10	24.71%	22.92%	26.92%
11–20	36.20%	38.54%	33.33%
20 +	23.56%	27.08%	19.23%
Highest Degree	N = 173	N = 96	N = 77
BA	36.42%	32.29%	41.56%
MA	61.85%	66.67%	55.84%
PhD	1.73%	1.04%	2.60%
Gender	N = 174	N = 96	N = 78
Male	59.77%	48.96%	73.08%
Female	40.23%	51.04%	26.92%
Race/Ethnicity	N = 169	N = 92	N = 77
White/Caucasian	95.86%	98.91%	92.21%
African-American	2.96%	—	6.49%
Hispanic	—	—	—
Other	1.19%	1.09%	1.30%

While there are proportionately fewer female teachers in the SI group (27%) compared to the CO group (51%), similar proportions were observed in previous investigations (29% female engineering teachers across 5 curriculum programs, versus 71% male engineering teachers in Daugherty, 2009; and 23% female PLTW teachers versus 51% female non-PLTW teachers in Nathan et al., 2010). The sampling appears to exhibit gender differences that are reflected among the population of engineering teachers and engineers in the workforce, more broadly (Clark, 2009).

When teachers were surveyed again in January 2009, we were able to document changes in their views and expectations due to the SI training and one semester of PLTW teaching. At retest, 36 SI teachers and 41 CO teachers completed the second survey. This design allowed us to track both initial differences in the beliefs and expectations among teachers with different teaching assignments, and to document the effects that preengineering professional development had on newly minted PLTW teachers, controlling for effects of survey retesting and time.

Each survey was administered online to all participants, using a secure system provided by the University of

Wisconsin. Participants read through and agreed to an IRB-approved consent statement, following federal guidelines for working with human subjects. All participants were offered $10 in compensation for their efforts each time they participated.

The EEBEI-T survey (Nathan et al., 2010) is made up of 42 Likert scale items across 7 previously tested constructs, along with 16 demographic questions. Below are two example survey items. A 5-point Likert scale (with a midpoint of 3) was used to rate teachers' beliefs about the *frequency* of occurrence of the events stated in some survey items. Item 8a shows a statement followed by the 5 choices, with the verbal anchors for each frequency scale score shown in parentheses.

> 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 Likert scale (with a midpoint of 4) was used for rating teachers' *levels of agreement* with statements. Item 6a shows a statement followed by the 7 choices, with the verbal anchors for each agreement scale score shown in parentheses:

> 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 visited a web link provided by email and, after giving consent for the study, selected the "radio button" that indicated their rating for each statement that was intended to match their own views. The online system ensured that only the choices provided were selected (no intermediate rating values were possible, for example). Because space on a page was not a factor for the online presentation, every item was accompanied by the complete set of verbal anchors for every numerical rating choice, minimizing errors due to forgetting or reversing of the scales.

Inclusion of the CO group the following winter allowed us to examine the changes in teachers' views when controlling for two important influences beyond just the effects of retesting. First, CO and SI teachers started out with some significant differences in their beliefs and expectations about engineering prior to the intervention. Baseline comparisons between the CO and SI group made these initial differences apparent and quantified them. It also provided empirical support for the claim that there very likely is some selection bias between the two samples, since teachers self-select for PLTW instruction. Since we are not in a position to experimentally randomize something as important and personal as who becomes a PLTW instructor, the baseline data allow us to control for these inherent differences. Second, if changes in views occur over time—as teachers mature, as historical events unfold that influence attitudes about engineering or education (such as a presidential election, or the release of the Grand Challenges), or simply as a result of retesting—these changes can also be controlled for statistically.

Results

In this section we report and interpret the ratings and selections that teachers gave during each of the survey administrations, before and after the SI group taught a PLTW course.

Teachers' Initial Beliefs and Expectations About Engineering Preparation

Table 2 summarizes the seven constructs from the Likert scale portion of the survey that were central to our study. The titles and verbal interpretation shown for each construct are inferred and did not appear anywhere on the survey, but are meant to help the reader understand the overall meaning conveyed across the range of items given. In addition, we show the total number of final items used in our analyses, followed by whether responses were along a 5-point or 7-point rating scale.

Constructs with a 5-point scale (Constructs A, B, F, & G) assessed teachers' views of the *frequency* with which specific conditions or events occurred. Mean ratings above 3 (Table 2) indicate that, on average, teachers believed that these conditions were more common than uncommon. Data from Construct A show that teachers' views overall were slightly above the midpoint of the scale, indicating that their lessons were sometimes shaped by students' academic performance. Construct B shows that teachers overall rate right near the midpoint of the rating scale, meaning that, as a group, they sometimes use students' interests and cultural backgrounds to inform classroom activities (though individuals in the group may be anywhere along the frequency range). The responses for Construct F show that teachers believe that they sometimes make the relation between science and math content to engineering activities explicit to students. Construct G reveals that teachers, as a group, believe their schools sometimes or infrequently provide resources such as career day or internships for students interested in engineering.

Constructs with a 7-point scale (Constructs C, D, & E) assessed teachers' levels of *agreement* with the given statements. A rating of 1 was used for strong disagreement, and 7 for strong agreement. Mean ratings below 4 indicate that

Table 2
Summary of Means and Construct Reliability Parameters for EEBEI-T Survey Administration Before a Subsample of Teachers Taught PLTW Courses for the First Time

Applicable to All Surveys			Survey #1 June 2008 (N = 182)	
Construct Title and Interpretation	No. Items	Scale [Mid]	Mean	α
A. **Influences on Instruction: Students' Academic Abilities**. My lessons are influenced by students' academic performance.	5	1–5 [3]	3.11	0.72
B. **Influences on Instruction: Students' Backgrounds and Interests.** I integrate students' interests and cultural backgrounds into classroom activities.	7	1–5 [3]	3.01	0.78
C. **Beliefs and Knowledge about Student Out-of-School Activities.** Students' science / math / technical learning takes place in the home and community.	5	1–7 [4]	5.70	0.79
D. **Careers in Engineering: Academic Achievement.** To be an engineer a student must have high academic achievement in science, math, and technology courses.	6	1–7 [4]	4.86	0.79
E. **Careers in Engineering: Social Network/Background.** The student whose parent is an engineer, who is male, and either white or Asian, is most likely to pursue engineering.	8	1–7 [4]	4.35	0.80
F. **Teaching for Engineering: Academic Courses.** The science and math content taught in my courses is explicitly connected to engineering.	3	1–5 [3]	3.23	0.91
G. **Environmental and Structural Support.** My school provides resources for students interested in engineering (e.g., internships, career day, professional development opportunities).	8	1–5 [3]	2.81	0.79

teachers generally disagreed with the statements. The responses from Construct C indicate that, as a group, teachers strongly agreed that students learn science, math, and technology in out-of-school settings such as the home or community center. Construct D shows that teachers generally believe that high academic performance in science, math, and technology, and technology courses is prerequisite to a career in engineering. Data from Construct E reveal that, on average, teachers believe that one's cultural or social background (e.g., parents as engineers, or being of Asian descent) is influential in one's decisions about pursuing a career in engineering.

To account for the indirect nature of survey measures and their inherent subjectivity, we performed internal consistency reliability analyses on the survey constructs using Cronbach's alpha (α), a measure that varies between 0 and 1.0 (Cronbach, 1951). The reliability analysis suggests that the EEBEI-T is a well-designed instrument. The relevant parameters are shown in Table 2 for the original sample (N = 182). First, mean ratings of each construct are near the center value for each scale, indicating that responses to these constructs are not statistically skewed. Second, the estimated values for Cronbach's alpha are all above .70, and most are nearly .8 or above, indicating a high reliability estimate (Black, 1999).

Differences in Teachers' Initial Beliefs and Expectations About Engineering Preparation

For most of the constructs (A, B, C, E), the differences between the SI and the CO groups were not statistically significant (see Table 3). However, the results show that the EEBEI-T exposes some statistically significant differences when comparing group means for other constructs (D, F, and G).

Three differences were identified. First, CO teachers were less likely to identify sources of support for engineering in their schools (construct G) than future SI teachers, $t(180) = -4.029$, $p = .000$. This result, while interesting, may simply be due to differences in the resources actually offered by schools with lesser and greater commitments to technical education and school-to-work transition programs. It is logical, for example, to imagine that those striving to teach PLTW in the future come from schools that already have a commitment to pre-college engineering. It also may signal differences in their awareness of the availability of resources. Of course, the actual presence of resources is not known, and CO and SI teachers might be applying different criteria when considering the availability of legitimate sources of support. Resolving this more definitively would entail documenting the actual programs available at each school, which, while outside the scope of this investigation, could prove to be a valuable area of future research.

Second, CO teachers agreed more strongly than the future SI teachers that to be successful in engineering, a student needs to demonstrate high scholastic achievement in science, math, and technology (construct D), $t(180) = 2.612$, $p = .010$. Here we see that teachers of math and science courses, which often serve a college preparatory function rather than emphasizing technical skills, see excellence in academic performance in a gatekeeper role for engineering. This finding replicates previous results showing differences among STEM high school teachers (Nathan et al., 2009). It also raises the issue about the differing purposes of K-12 engineering programs and the intended student clientele. Those who expect that high scholastic achievement in science, math, and technology is pre-requisite to participation in engineering studies may consider high school

Table 3
Differences in Ratings of Teachers Prior to Summer Institute (N=182)

	Mean (Standard Deviation)		Independent Samples t-Tests	
Construct	CO (N = 100)	SI (N = 82)	*t*	*p*
A. Influences on Instruction: Students' Academic Abilities	3.04 (.516)	3.19 (.618)	–1.788	.075
B. Influences on Instruction: Students' Backgrounds and Interests	2.97 (.597)	3.06 (.541)	–1.038	.300
C. Beliefs and Knowledge about Student Out-of-School Activities	5.64 (.796)	5.78 (.720)	–1.275	.204
D. Careers in Engineering: Academic Achievement	5.02 (.960)	4.66 (.890)	2.612	.010*
E. Careers in Engineering: Social Network/Background	4.3 (.782)	4.42 (.903)	–.976	.330
F. Teaching for Engineering: Integration of Academic Concepts and Engineering	2.87 (.909)	3.67 (.912)	–5.936	.000*
G. Environmental and Structural Support	2.60 (.760)	3.07 (.807)	–4.029	.000*

* $p < .05$.

engineering as a kind of "pre-engineering" program that should be reserved for a selective group of students who demonstrate a history of excelling in technical courses and are more likely to pursue a STEM field of study. Those who do not espouse a selective view may see engineering studies as contributing more broadly to the technological literacy of all well-educated students (Katehi et al., 2009). While both the CO and SI groups show average views that affirm the essential importance of high academic achievement, the CO group, on average, exhibits this view far more strongly, suggesting a potentially important ideological division. This division reflects ideological differences between the science and engineering education communities more broadly (Nathan et al., 2010).

Third, even before teaching PLTW courses, SI teachers were more likely than CO teachers to claim that science and math content taught in their classes was integrated with engineering content (construct F), $t(180) = -5.936$, $p < .001$. We note that this integration can, in principle, be made in both directions: College preparatory courses may elect to use engineering context to motivate the science and math and to demonstrate its applicability in "real world" problem-solving tasks; and engineering courses may highlight the roles that science- and math-specific topics play in engineering design and analysis. This difference between CO and SI teachers suggests that teachers drawn to using the PLTW curriculum are more likely to enact or to see points of integration between their science, math, technology, and engineering content. Since the responses are based on teachers' self reports, it is also possible that these different groups of teachers may have different criteria for what it means for math and science concepts to be integrated into engineering education activities. As the National Academy Panel (Katehi et al., 2009) noted, STEM integration, while lauded in national education policy, is elusive.

Changes in Teachers' Beliefs and Expectations About Engineering Preparation

By January, the main divergence between the groups was that SI teachers attended the two-week PLTW summer training institute and then went on to teach PLTW in their high schools for one term. A second administration of the EEBEI-T was given in January 2009. Out of the original sample, 77 teachers responded to the invitation to take the second survey, including 36 SI teachers, and 41 CO teachers who served as our comparison subjects. It should be noted that those in the SI group were high school science, math and technical education teachers who, like the control group, had not previously taught in the PLTW program before this study.

Administering the second survey the following winter allowed us to investigate changes in teacher views once the new PLTW teachers applied the concepts and skills learned during the summer institute to their classrooms. Since significant psychological traits do not easily change (e.g., over the two week period of the summer institute), this was regarded by the research team as a more authentic way to measure the impact of new PLTW instruction on teachers' views.

Because of the reduced response rate for the second survey administration, comparisons between groups and from June 2008 to January 2009 are now presented exclusively for only those teachers who provided complete data at both points in time. Comparisons (summarized in Table 4) show change data for CO teachers (N = 41) and SI teachers (N = 36).

As reported on the baseline survey, CO teachers were more likely than SI teachers to believe that high academic achievement in science, math, and technology courses was necessary to become an engineer (Construct D), and this group difference showed no change over time. We also learned that teachers in both groups initially reported that they did not strongly address students' interests and cultural backgrounds when designing classroom instruction (Construct B). At retest, regardless of PLTW training, teachers reported attending to student background and interest *less* than they reported at time 1, $F(1, 75) = 4.04$, $p = .048$. This may well be a general effect in response to the increasing accountability climate of high stakes standardized testing that is driving greater focus on "teaching to the test" (Neill, 2003).

SI teachers started out more positive about the institutional support they experienced for engineering at their schools (Construct G) than control teachers, and this difference grew significantly over time. Statistically, we found a significant main effect of group $F_{Group}(1,75) = 20.96$, $p < .001$ (SI higher than CO), a significant main effect for time,

Table 4
Means (and Standard Deviations) of Construct Scores for Those Control (CO, N = 41) and Summer Institute (SI, N = 36) Teachers Who Participated in Both Spring 2008 and January 2009 Survey Administrations

	CO (N = 41)		SI (N = 36)	
Construct	Survey 1	Survey 2	Survey 1	Survey 2
A. Influences on Instruction: Students' Academic Abilities	3.03 (.493)	3.09 (.473)	3.11 (.531)	3.21 (.445)
B. Influences on Instruction: Students' Backgrounds and Interests	3.06 (.594)	2.91 (.547)	2.95 (.464)	2.86 (.507)
C. Beliefs and Knowledge about Student Out-of-School Activities	5.64 (.616)	5.61 (.686)	5.82 (.743)	5.64 (.862)
D. Careers in Engineering: Academic Achievement	5.10 (.816)	5.02 (.783)	4.75 (.962)	4.53 (.892)
E. Careers in Engineering: Social Network/Background	4.25 (.688)	4.39 (.707)	4.58 (.796)	4.55 (.726)
F. Teaching for Engineering: Academic Courses	3.02 (.830)	2.76 (.778)	3.61 (.885)	4.08 (.798)
G. Environmental and Structural Support	2.55 (.752)	2.52 (.773)	3.15 (.806)	3.42 (.716)

Table 5
Summary of the Content of the 4 Student Vignettes

	Vignette 1 (V1)	**Vignette 3 (V3)**
Compares Academic Performance (controlling for SES and Gender)	*Gender:* Male *Grade:* 10th *Background:* low SES *GPA:* 3.85 Interests Wants to enroll in Principles of Engineering; attend college.	*Gender:* Male *Grade:* 10th *Background:* low SES *GPA:* 1.35 Interests Assembling body kits on foreign cars; wants to attend college.
	Vignette 2 (V2)	**Vignette 4 (V4)**
Compares SES (controlling for Academic Performance and Gender)	*Gender:* Female *Grade:* 11th *Background:* high SES *GPA:* 3.45 Interests Wants to enroll in Digital Electronics; thinks father's work as an engineer is "cool."	*Gender:* Female *Grade:* 11th *Background:* low SES *GPA:* 3.45 Interests Wants to enroll in Digital Electronics; uninterested in her parents' blue-collar jobs.

Vignettes 1 and 3 (row 1) compare academic performance, controlling for student social background, while vignettes 2 and 4 (row 2) compare socioeconomic status (SES) while controlling for academic performance.

$F_{\text{Time}}(1,75) = 4.154$, $p = .045$ (more over time), and a significant group by time interaction, $F_{\text{GroupXTime}}(1,75) = 6.24$, $p = .015$. Analysis of the specific responses showed that while CO teachers remained essentially constant in their views, SI teachers showed a marked increase after the training and teaching experiences.

Finally, SI teachers initially believed more strongly than CO teachers that the math and science concepts taught in their courses were explicitly connected to engineering (Construct F), $F(1, 75) = 34.45$, $p < .001$. The retesting of beliefs showed that for this sample of teachers this gap grew, due both to stronger agreement among SI teachers and stronger disagreement among CO teachers over time, $F(1, 75) = 15.78$, $p < .001$.

Measuring Teachers' Contextualized Judgments Using Student Vignettes

Vignettes of fictional high school students were included in the EEBEI-T to contextualize teachers' judgments about students and use comparisons between the fictitious profiles to identify factors that may influence teachers without explicitly drawing teachers' attention to them. The four vignettes (Table 5) used were specifically designed to address two factors: comparisons between V2 and V4 vary social influences such as students' SES, while the V1-V3 comparison examines the influence of academic factors such as students' prior course grades and cumulative GPA. Each pair controls for gender and the other factor of interest, but does so in an implicit manner. An example vignette is provided in Appendix A.

Teachers were directed to read each vignette and then provide the following responses: (a) recommend whether a student should enroll in a precollege engineering course the following year, (b) specify the criteria the teacher used to make that recommendation (e.g., prior academic performance, overall GPA, gender, age, SES, family background), and (c) offer a prediction of success for the student's future as a working engineer. Findings from the Likert scale data (Construct D) lead us to predict that teachers would tend to favor students with high academic performance and therefore favor enrollment for V1, V2, and V4. Teachers also reported that SES had little sway with their decision-making processes and so we should therefore expect that V2 (female with high SES) would not receive any greater support than other high GPA students (the other female, V4, or the male, V1) from lower SES families.

Teachers' responses to the vignettes were analyzed using an ANOVA with Vignette (4 levels, a within-subjects factor and repeated measure for each of the 4 student profiles), Group (2 levels, a between-subjects factor for SI vs. CO), and Time (2 levels, a within-subjects factor), along with the interactions of these factors. Our dependent variables were the proportion of teachers who: endorse enrollment of a student vignette, report the use of any of several factors in making their endorsement judgment, and predict success in an engineering career track for each vignette.

A number of planned pairwise contrasts were also conducted to determine differences between the vignettes,

provided a significant omnibus main effect of Vignette was found. We used Shaffer's (1979) *sequentially rejective multiple test procedure* to control the Type I error rate of 0.05 across the pairwise contrasts for each factor. For example, for an effect with six possible pairwise comparisons, contrasts were ordered by significance and their *p*-values compared to the allowed Type I error rates as follows: .05/3, .05/3, .05/3, .05/3, .05/2, and .05/1 (i.e., the denominator is equal to the number of type I errors which could have still been made). To make the strongest theoretical claims, we focused our presentation of results for contrasts to those pairs of vignettes that supported the most direct comparisons (Table 5). Comparisons between V1 and V3 allowed us to compare the effect of academic factors while controlling for gender (both male) and SES (both low). The V2-V4 comparison allowed us to compare the effect of SES on teachers' judgments while controlling for gender (both female) and academic performance (both high). The V1-V3 and V2-V4 contrasts will be the focus of the results reported below.

Endorsing Student Enrollment

Teachers were asked of each vignette "Would you encourage this student to enroll?" Our analyses of teachers' responses for the omnibus question on endorsement of enrollment into a pre-engineering course revealed a significant overall main effect for vignette ($p < 0.001$). This indicates that the level of endorsement depended on which vignette teachers responded to. As Figure 1 shows, endorsement to enroll was generally high, but substantially lower for V3 (male with low GPA) than the others, and somewhat lower for V4 (female with low SES).

Because of the way the profiles were designed (Table 5), pairwise contrasts between vignettes allowed us to infer the actual (rather than reported) influences of academic and social factors. Both the V1–V3 and V2–V4 contrasts were significant ($p < 0.001$). This shows that teachers in our sample were influenced by both academic and social factors in making their enrollment recommendations. Specifically, teachers were more likely to encourage those with higher academic performance and those with higher SES to enroll. The influence of academic performance is consistent with the Likert scale findings above (Construct D) showing that STEM teachers tend to agree that to be an engineer a student must have high academic achievement in science, math, and technology courses. The influence of SES is somewhat surprising, however. It may reflect a wide array of views. Our interest, explored in the following section, is how teachers report on the factors they used to make these decisions.

In addition to the main effect of Vignette, the Enrollment measure entered into a significant interaction ($p = 0.042$) with Time and Group (Figure 2). The interaction highlights opposing shifts in beliefs between CO and SI teachers over time: Our intervention group, SI teachers who only first taught PLTW, decreased their support for student enrollment in engineering classes over time (regardless of which student profile they were considering), while control teachers increased their level of encouragement during the same time period. While the pattern is intriguing, and many plausible reasons spring to mind (e.g., PLTW teachers develop a more realistic understanding of the expectations of the PLTW courses, while CO teachers are warming up to the idea from repeated exposure), these data provide little

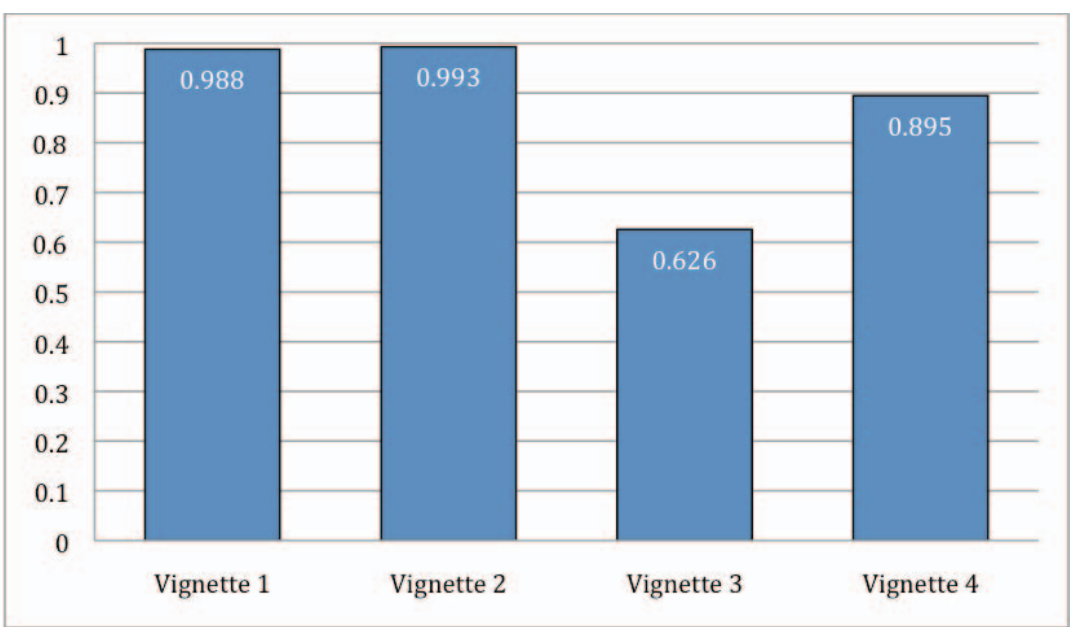

Figure 1. Proportion of STEM teachers endorsing the fictional students in vignettes 1 through 4 to enroll in high school engineering classes.

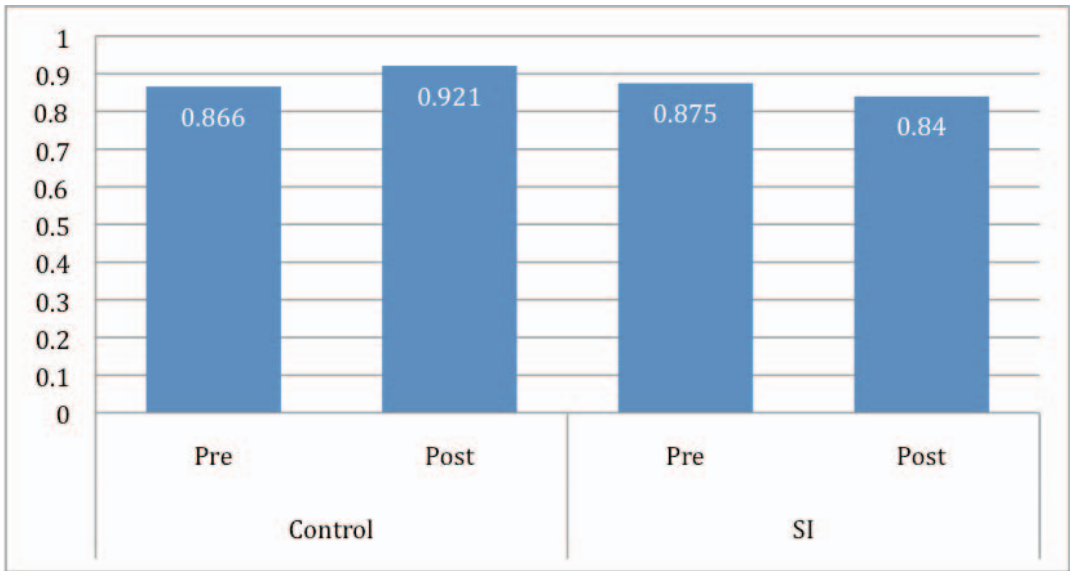

Figure 2. The Time by Group interaction showing decreased support for enrollment by SI teachers over time, but increased support by control teachers.

to uncover the actual basis for the effect. We recommend further research in this area.

Factors that Teachers Report as Influencing Their Endorsements of Student Enrollment

Teachers were given a set of seven factors and asked to indicate which, if any, they used in making their enrollment decisions. Of these omnibus tests, significant main effects of Vignette ($p < 0.005$) were found for Academic history, GPA, Family, Student Interest, and Gender. As is evident in Table 6, Gender received so few supporters that the omnibus test, while significant, is not that meaningful; the result is due to a small but measurable level of support for the Gender factor for V2 (4% of teachers) and V4 (1%), coupled with no support for V1 and V3. While other vignette contrasts showed an effect for Gender, it was because they were comparisons with one of the vignettes that received no support (V1 or V3).

Family was rarely endorsed as a factor, so even occasional consideration led to both an omnibus effect and pairwise effects, particularly for V2 versus V4, where V2 expressed that she thought her father's work as an engineer was "cool." SES was not significant as a factor in the omnibus test, but SES is unique in that *none* of the teachers reported using it explicitly as a factor. This response pattern is also notable since overall higher levels of endorsement for V2 (high SES) compared to V4 (low SES) implicates SES as an *implicit factor* in teachers' decision making. The vignette data show that teachers tended to favor enrollment of the higher SES student, but based on their identification of influential factors we see that teachers apparently have no awareness that SES influences these decisions.

Differences between V1 and V3 that signal teachers' sensitivity to academic considerations were found in all three of the remaining influences reported by teachers: student's current academic performance (Academic), student's past academic performance (GPA), and student interests (Interest). In each case, teachers were more likely to report these as factors influencing endorsement when the vignette's profile indicated higher academic achievement. Said another way, fewer teachers reported weighing students' academic record when that student had a lower academic record, but they tend to use it to justify endorsement decisions for academically strong students. Teachers were also more likely to predict success in engineering for the higher academically performing student (V1), in keeping with the Likert scale data above.

SES differences (evident in significant contrasts between V2 and V4) were significant for GPA and Academic ($p < 0.001$), but not for students' interests. Teachers reported these academic factors as contributing to their decisions on enrollment in greater numbers when reviewing the profile for the higher SES student (V2) than low SES students. Additionally, teachers were more likely to predict that the higher SES student would have a successful career in engineering, even though there were others with comparable academic track records. In the final section we discuss these differences in the broader context of who should have access to K-12 engineering education.

Discussion

In this final section we re-examine our findings in light of the challenges and opportunities that STEM integration in the classroom poses, current efforts to attract a more

Table 6
Means, Standard Errors (SE), and Effect Sizes (ES) for Teachers' Responses to Questions Involving the Vignettes

	V1	V3	V1 *vs.* V3		V2	V4	V2 *vs.* V4	
Question	Mean (SE)	Mean (SE)	*p*	ES	Mean (SE)	Mean (SE)	*p*	ES[1]
Would you encourage this student to enroll?								
	0.99 (.01)	0.63 (0.04)	0.00*	.45	0.99 (0.01)	0.89 (0.02)	0.00*	.16
Which criteria were used in your enrollment decision?								
Academic	0.80 (.04)	0.43 (0.05)	0.00*	.45	0.77 (0.04)	0.50 (0.05)	0.00*	.28
GPA	0.63 (.04)	0.30 (0.04)	0.00*	.49	0.55 (0.04)	0.36 (0.04)	0.00*	.28
Gender	0.00 (.00)	0.00 (0.00)	—[2]	—[2]	0.06 (0.02)	0.05 (0.02)	0.66	.00
Family	0.02 (.01)	0.08 (0.02)	0.01*	.08	0.33 (0.04)	0.03 (0.01)	0.00*	.42
Interest	0.92 (.02)	0.60 (0.05)	0.00*	.39	0.91 (0.03)	0.84 (0.03)	0.04	.05
Age[3]	0.07 (.02)	0.06 (0.02)	*N/A*	*N/A*	0.06 (0.02)	0.04 (0.02)	*N/A*	*N/A*
SES[3]	0.00 (.00)	0.00 (0.00)	*N/A*	*N/A*	0.00 (0.00)	0.00 (0.00)	*N/A*	*N/A*
Would you predict future success in an engineering career?								
	.63 (.05)	0.08 (0.02)	0.00*	.64	0.66 (0.04)	0.18 (0.03)	0.00*	.61

* All contrasts marked with an asterisk are significant at the appropriate level using the Shaffer method as described in the text to control Type I error rate for each question/factor to .05.
1. The effect size represented in this table is for partial eta squared.
2. Because no teacher endorsed Gender as a factor for V1 or V3, the V1-V3 pairwise comparison cannot be conducted.
3. Age and SES did not have significant main effects of vignette and therefore results from pairwise comparisons were discarded.

diverse set of students and practitioners into engineering, and ways in which differences in teacher beliefs and expectations are indicative of broader tensions about the purpose and place of K-12 engineering education. First, however, we address some of the methodological issues of conducting research on teachers' initial and changing beliefs, and summarize our findings.

Reflections on the Research Methodology

Investigation of the impact of education programs on a select group of participants is an inherently challenging enterprise. In some cases, the assignment of participants to treatment and control conditions is entirely under the direction of the team of researchers and school leaders. However, it is also often the case that assignment is not under the researcher's control, but determined by the participants themselves, perhaps in consultation with parents, teachers, and others. Consider the makeup of students who opt to enroll in engineering classes in their high schools. To deny (or even delay) access to suit research faces serious ethical barriers, since it withholds from students and parents their preferences, and could impose serious damage to their scholastic progress and even later academic and workplace opportunities.

In a somewhat similar manner, teachers decide for themselves whether to participate in or avoid engineering instruction. Manipulating this selection for research purposes also incurs serious professional and ethic issues. This study is a quasi-experimental design in that participants were not randomly assigned to either condition; teachers in each group self-selected whether they would become PLTW teachers. With limited ability in public schools to assign teachers to their classes and the associated professional development experiences, there is a need to document inherent differences that may exist among teachers even prior to the interventions that knowingly distinguish them, and to interpret the impact of training and teaching experiences within the context of pre-existing differences. Quasi-experimental design research methodology may not be considered to be the "gold standard" by every deliberating body (Cook, Shadish, & Wong, 2008; Shavelson & Towne, 2002; US Department of Education, 2003), but it is a highly effective method for addressing many of the practical constraints that arise within authentic educational settings (cf. Tran, Nathan, & Nathan, 2010).

Summary of Findings

Responses on the Likert scale items showed that, as a group, the teachers in our sample agreed strongly that STEM education takes place in a variety of settings, including outside of formal schooling. They tended to believe that academic achievement was a precondition for engineering success, that social network and family history shape who will pursue engineering, and that their schools sometimes or infrequently provide institutional support for engineering.

Consistent with the Likert scale findings, teachers' responses to the situated vignettes showed the importance of academic achievement on teachers' decision making about who should enroll in future engineering classes and their predictions of who would be most likely to succeed in an engineering career. The vignettes also provided a more nuanced view of the influence of student academic record. While, on average, enrollment was advocated nearly 90% of the time, a breakdown of the criteria teachers used showed that

teachers tended to justify their endorsement on academic grounds more often when the student profile showed high performance. When low performance was evident, teachers turned to other criteria to justify their endorsements.

The vignette data also reveal a kind of disconnect between the actual influences on teachers' judgments and the influences of which teachers are aware. When asked explicitly, teachers did not cite student SES as an influence on their decisions. However, teachers favored students from high SES families for course enrollment and predicted higher rates of success for those from more privileged circumstances. Little from the data reveals the basis of these influences. This pattern, however, is notable given the current drive to attract more diverse groups to engineering studies and careers. This point is explored further in the next section.

One additional pattern of note in the baseline data is that, over time, the levels of endorsement offered by SI and CO teachers diverged. Control teachers increased their level of support of course taking from the first to the second survey, while support from SI teachers decreased. Though the data are limited in explaining this pattern, SI teachers formed a realistic understanding of the demands of the PLTW program that might have shifted their criteria.

We also found pre-existing differences between SI and CO teachers. Specifically, budding PLTW SI teachers were more likely to identify sources of support for engineering in their schools and report that science and math concepts were being integrated with engineering activities during their instruction. CO teachers agreed more strongly of the prerequisite role of high scholastic achievement in science, math, and technology, and technology for engineering studies.

Finally, we were able to identify changes in teachers' views *above and beyond* pre-existing group differences and changes that naturally occurred over time. Teachers who did the PLTW training and taught it for the first time increased their reporting that STEM curriculum materials were being effectively integrated in their classes. This echoes findings from other professional development programs (e.g., Cunningham, 2009). Because of the specialized role that teachers play in determining instruction, their attitudes and perceptions about STEM integration in the classroom is an area of central importance, which is explored more below.

Limitations of the Current Study

The current study has several limitations. First, teachers were not randomly assigned to either of the two conditions, but self-selected on the basis of whether they were interested in becoming a PLTW teacher. Consequently, this study employed quasi-experimental design methodology, whereby it is only possible to account for observable differences between treatment and control groups; any unobservable differences due to sampling biases between conditions cannot be addressed by this analysis. A future study that could randomly assign teachers to condition may face serious practical challenges, but would provide for greater generalizability of the experimental results.

Second, internal validity may be compromised by selection bias for participants who completed the postintervention survey (42% response rate). However, a chi-square test for homogeneity of proportions showed no significant differences in proportions in each demographic category between the original groups and matched groups for either CO or SI. In fact, the demographic compositions of the summer and winter samples were remarkably similar.

Third, external validity may be limited by the characteristics of our teacher sample. A large proportion of the teachers was White, was male, and had more than 10 years of teaching experience. Therefore, teachers in our sample may be different from teachers in the general population. A fourth limitation is that the results were derived from self-reported data from teachers. While this was common across all participants, it is possible that differences between teachers in the SI and CO groups actually reflect differences in their understandings or interpretations of what the survey items convey rather than true differences in their beliefs and practices. Other data collection methods such as interviews, classroom observations, ethnographic study of classroom practices, while intrusive, would provide another perspective on the nature of teacher instruction. Finally, while we might anticipate that this study contributes to an understanding of pre-engineering education in secondary schools more broadly, we caution the reader that the results have only emerged from study of a specific pre-engineering curriculum.

Current Initiatives to Broaden the Engineering Pipeline

Engineering educational programs and engineering professions both face well-entrenched historical patterns that tend to exclude females and a number of non-Caucasian and non-Asian ethnic groups, particularly African Americans and Hispanics (Wulf, 1998). Consequently the demographics of course enrollments, graduating classes, and the engineering workforce do not match the demographics of the country as a whole. This has several consequences. It withholds from many talented youth the economic opportunities that follow from technical degrees and careers. It also shows a lack of "cultural competence," where engineering presents itself as insensitive to cultural aspects of society and less relevant to members of other cultures (Chubin, May & Babco, 2005). The lack of a diverse workforce also prevents engineering firms from being responsive to the shifting technological needs of a rapidly changing population that is becoming more subject to the demands of a globalized marketplace (Katehi, Pearson, & Feder, 2009). In this vein, we observed implicit views about student SES among STEM teachers in our sample that could perpetuate stereotypes of who should have access to highly rewarding technical education programs and who is likely to succeed in an engineering career. The homogeneity of the engineering

workforce reinforces a cycle of exclusion that is invisible to teachers yet effective in blocking systemic change.

Challenges and Opportunities of Providing STEM Integration

Along with a growing urgency for promoting student understanding of the individual facets of science, technology, engineering, and mathematics has come a drive to reconceptualize instruction in terms of STEM integration that would break down traditional curriculum "silos" (Katehi et al., 2009). This comes, in part, from federal initiatives such as "Race to the Top" (Chang, 2009), policy documents (Committee on Standards for K-12 Engineering Education, 2010; NRC, 2007), and learning sciences research aimed at fostering greater transfer of knowledge (e.g., Pellegrino, Chudowsky, & Glaser, 2001). To this end, the 2006 Reauthorization of the Perkins Career and Technical Education Act (Public Law 105-332, 1998) mandates that technical education and academic math and science topics must be integrated "so that students achieve both academic and occupational competencies" with substantial funds allocated "to provide vocational education programs that integrate academic [math and science] and vocational education." PLTW and other commercial curricula take up this mandate toward STEM integration. As they state in their marketing materials: "The combination of traditional math and science courses with innovative Pathway to Engineering courses prepares students for college majors in engineering and E/T fields and offers them the opportunity to earn college credit while still in high school" (PLTW, 2009).

It is notable, then, that our main finding is that the PLTW intervention seems to instill in new PLTW teachers a sense that they are better able to meet this mandate and provide instruction that more consistently integrates concepts from math and science into the engineering activities in their classrooms. By encouraging an integrative outlook on engineering instruction, PLTW engineering students are expected to make the conceptual connections needed to ground their academic knowledge to real world applications, while at the same time developing a greater understanding of how the specific ideas and procedures that they encounter in an engineering context will generalize to new problems and application areas.

Schunn (2009) has argued that STEM education implies an integrative curriculum that reveals a synergy that goes beyond the constituent parts (also see Moore, Roehrig, Lesh, & Guzey, in review). He singles out math—"the language of physical sciences and engineering sciences"—as "critical" to achieving this synergy. However, recent investigations of engineering curricula, classroom instruction, and student achievement point to the challenges of realizing effective STEM integration in K-12 education (Katehi et al., 2009; Nathan, Oliver, Prevost, Tran, & Phelps, 2009; Nathan, Tran, Phelps, & Prevost, 2008; Prevost et al., 2009; Tran & Nathan, 2010a, 2010b; Welty et al., 2008). Schunn identified several formidable obstacles for fully conceptualizing the integration of math with engineering and other STEM fields: To attract students who are otherwise weak or lack confidence in their math abilities, its presence in technical fields is systematically diminished; teachers in nonmath STEM fields often lack math knowledge and math-specific teaching experience to carry out integration effectively; and the ever-present limits on time in the curriculum.

Schunn (2009) notes that several workable methods can enhance the level of integration; among these, he names using the new topics and contexts from engineering or technology to reinforce mathematical understanding and application. Moore (2008) adapted Model Eliciting Activities (MEA) from math education to engineering education. She has shown that MEAs serve to elicit student thinking as well as provide a pedagogical structure for the design and implementation of complex, collaborative activities in engineering classrooms that effectively integrate each of the STEM disciplines. Stone and colleagues (2008) achieved student gains on standardized math tests through STEM integration using a professional development program that emphasized ways for teachers to regularly and explicitly integrate mathematics concepts with career and technical education (CTE) lessons.

The desire to advance students' thinking in multiple STEM areas through integration, coupled with the practical challenges of implementing far-reaching changes in teacher preparation and curriculum design highlights, signal the challenges and opportunities that lay ahead for education reform. It also is a reminder of the important role of teachers as change agents for enacting systemic reform initiatives, and the value of understanding teachers' expectations, attitudes, and beliefs about engineering education.

Conflicting Purposes of K-12 Engineering Education

Within K-12 engineering education there is a persistent conflict between allocating limited educational resources to programs that provide pre-engineering and focus on identifying and educating promising scientists for technical careers, and those that promote a broader agenda of technological literacy "for all" even though most citizens will never pursue technical fields of study or careers. This division plays out in national policy discussions and in local schools districts throughout the United States (Katehi et al., 2009). The teachers in this sample provide a microcosm of the nation in this regard. On one hand, even before the intervention, budding PLTW teachers identified greater institutional resources that supported engineering education in their schools than the other STEM teachers (Construct G). On the other, those STEM teachers who did not go on to teach PLTW believed more strongly than PLTW teachers that academic achievement in science and mathematics must be a "gatekeeper" for access to engineering studies (Construct D). Differences in beliefs of this kind have implications for the perceived purpose and place of engineering education (Custer & Daugherty, 2009). The role that an

individual's science and math knowledge plays in the collaborative and globalized nature of engineering professional practice is not clear cut (Anderson, Courter, Nathans-Kelly, Nicometo, & McGlamery, 2009; Gainsburg, 2006). The survey data suggest, however, that whatever the nuanced role is, nascent PLTW teachers come in with more inclusive values about engineering education than the broader STEM teacher population even before the intervention, and, by signing on to become an engineering teacher, clearly took concrete actions to extend the reach of engineering into the lives of a broader array of high school students.

Appendix A: Example Vignette

Vignette 4

Janet is enrolled in the 11th grade at your school with an overall GPA of 3.48 on a 4.0 scale. She is qualified to receive federal free/reduced lunch. She is liked by many of her peers and teachers. Janet plans to attend college after she graduates from high school. Janet is uncertain about her career plans and would like to learn more about different career choices. Her mother is a part-time waitress at a local restaurant and her father is a construction worker with 20 years of experience. The jobs her parents hold do not seem interesting to Janet. She expressed her interest in enrolling in a pre-engineering course called *Digital Electronics* for the pre-engineering curriculum purchased by your school through the career technical education program in your district. Janet is currently enrolled in a pre-engineering course called *Introduction to Engineering Design*.

Below is a list of courses she is currently enrolled in this semester along with the midterm grade for each course.

Period 1: English 11—Grade: B
Period 2: Introduction to Engineering Design—Grade: A
Period 3: Pre-Calculus—Grade: A
Period 4: Economics—Grade: A
Period 5: French 3—Grade: B
Period 6: Physics—Grade: B

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