AC 2011-1693: PERCEIVED BARRIERS TO PARTICIPATION IN ENGINEERING:

Yvette Pearson Weatherton, University of Texas, Arlington

Dr. Yvette Pearson Weatherton received her Ph.D. in Engineering and Applied Science (Environmental Engineering) from the University of New Orleans in 2000. She is currently a Senior Lecturer in Civil Engineering at the University of Texas at Arlington. Dr. Pearson Weatherton's expertise is in the areas of air quality including monitoring and modeling and engineering education. She is currently PI or Co-PI on a number of NSF-funded engineering education projects including "UTA RET Site for Hazard Mitigation", "UTA REU Site for Hazard Mitigation and "Focus On Retention in Cohorts of Engineering Students", which provided data for this study. Dr. Weatherton is a registered Professional Engineer in Louisiana.

Stephanie Lynn Daza, University of Texas at Arlington

Dr. Daza's work focuses on research methodology, theories of difference, and globalizing trends in educational policy and practice. Her work has been published in The International Journal of Qualitative Studies in Education and Race Ethnicity and Education. She completed her PhD in Social and Cultural Foundations with a focus on research methodology at The Ohio State University in 2006. Prior to this, Stephanie was a US Peace Corps Volunteer in Bolivia and a high school teacher in California.

Vu V. Pham, University of Texas at Arlington

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Perceived Barriers to Participation in Engineering: Why Underrepresented Groups Remain Underrepresented

Abstract

This study examines barriers that are perceived to prevent successful enrollment and matriculation of students from underrepresented groups in engineering. Data includes surveys administered to high school math and science teachers and their students. Around 50 high school teachers and over 1,200 high school students have been surveyed during the process of collecting assessment data for the NSF-sponsored UTA Research Experiences for Teachers in Hazard Mitigation. Survey data is illuminated and supported by data collected from teacher focus groups, classroom observations and teacher-produced materials such as lesson plans and reflective papers. Additional data was collected by surveying undergraduate engineering students.

For each group (e.g. High School STEM Teachers, High School STEM Students, and Undergraduate Engineering Students), key findings regarding the group's perception of barriers for underrepresented populations are discussed. Perceptions of barriers are organized by disability, gender, and race/ethnicity. Concluding remarks discuss some of the themes reflected across groups, including how curriculum, identities, and self-perceptions are constructed based on traditional norms and historically held biases about gender, race/ethnicity, and (dis)ability.

While there are similarities of perceived barriers among high school students, high school teachers, and undergraduates, the analysis of our data shows that perceptions are not uniform among participants, but rather that they perceive curricula, instruction, student differences, engineering, and engineers differently. Our data suggests that approaches to diversifying engineering need to consider perceptions, as well as be multipronged and differentiated.

Introduction

Engineering education faces a number of challenges, including the inadequate preparation, mentoring and socialization of women, ethnic minorities and people with disabilities (underrepresented groups) to engineering careers. Although there have been improvements in the numbers of engineering degrees awarded to people in these underrepresented groups over the past few decades, there is still much work to be done to diversify the profession to reflect the country's shifting demographics and to broaden perspectives used in developing new technologies and solving complex problems.

The importance of diversity in the engineering workforce has been recognized as a priority by a number of entities, including the National Academies. Engineers from diverse backgrounds and experiences are needed to devise creative solutions to the challenges posed by a diverse and more interconnected world.[1] Recruitment of a diverse engineering workforce includes the successful recruitment, retention and graduation of a diverse engineering student population. In order to accomplish this, barriers that hinder females, minorities and people with disabilities from earning engineering degrees must be identified and ultimately overcome.

Research shows that prevailing perceptions of engineers and engineering continue to exclude underrepresented groups. For example, students and teachers often perceive engineers and scientists in narrow ways—such as "intelligent Caucasian men who are socially inept and absent-minded" and who work in isolated settings.[2] In order to examine factors that are perceived as barriers, our study explores the perceptions, attitudes and beliefs held by three groups of participants – high school students, high school teachers and undergraduate engineering students – including the perceptions of members of underrepresented groups of curricula, instruction, student differences, engineering, and engineers.

Relevant Literature: Providing a Backdrop for the Study

According to the National Center for Education Statistics' High School Longitudinal Study of 2009 (HSLS:09), "Policy innovations to increase and retain STEM college majors have been proposed, but little is known about the factors at the secondary school level that may affect the supply of possible STEM students in college and beyond;" and there is a need for understanding student perceptions of school generally and STEM specifically, particularly regarding "identity formation; academic behavior (e.g., attendance, study habits); attitudes and beliefs (e.g., self-efficacy); social and cultural experiences; exposure to STEM through school or home activities; negative school and STEM experiences."[3]

Research does show that teachers and students of all levels hold narrow perceptions of engineers and engineering.[4-8] Yet, teachers' perceptions influence student learning and student perceptions mediate their choices of study and persistence. According to Matusovich et al., "we need a deep-rooted understanding of the students' perspectives …. [but] little existing research on persistence in engineering has been conducted from the student perspective…"[9] Moreover, since teachers' beliefs have an impact on student learning,[10] Nathan et al. "point to the importance of documenting teacher beliefs in advancing our understanding of the influences on students' future academic performance and success in engineering."[11] Furthermore, research on engineering undergraduates shows that student attitudes about themselves and perceptions about engineering provide valuable information about attrition and persistence. For example, some research has found that initial attitudinal differences are attributable to the students' gender and ethnic background and that retention is more linked to students' attitudes and perceptions than to their academic credentials. [12-16]

Regrettably, women and minorities remain underrepresented in Science, Technology, Engineering, and Math (STEM) education programs and career fields, despite efforts to diversify these fields in the recent decades.[17] For example, although for the first time more doctorates were earned by women (50.4%) than men, doctoral degrees for women in most STEM fields actually decreased.[18] In addition, approximately 7% of employed scientists and engineers are persons with disabilities, while 13% of the working-age population of the US (ages 21-64) have disabilities (based on 2006-07 data). In 2008, 10.4% of students enrolled in undergraduates engineering and computer science programs were documented as having disabilities.[19] Finally, it is important to note that Whites outnumber all minorities by almost three to one across all disciplines and careers.[20]

Similarly, about 80% of the teacher workforce identifies as White, English-speaking, heterosexual, middle-class females. However, while nearly all science and mathematics teachers in grades K–4 are female, there is a shift from female to male teachers in later grades: to approximately three-fourths females in grades 5-8, and to about half in grades 9-12.[21] Moreover, minorities of color make up only 9–14% of the science and mathematics teachers, depending on subject and grade range, while roughly 40% of enrolled students are minorities.[22] Although much is made of the fact that the US teaching workforce, especially in public schools, is less racially and ethnically diverse then the populations they teach,[23-25] homogenizing race/ethnic and gender groups ignores the various backgrounds, experiences, values, and beliefs within groups. Diversity and dissimilarities within all groups should be assumed. As Daza has written about elsewhere, while similar language, skin color, and other identity markers may be important to understanding structural inequities, they do not necessarily indicate group affiliations or unified views.[26]Along this same line, the category of 'Asian' includes diverse and disparate populations;[27,28] yet because STEM includes more Asians than their level in the general population, Asians are not considered an "underrepresented" minority in STEM.

In sum, while the lack of diversity in engineering is well documented and the call and efforts to diversify STEM has come from every direction imaginable, including universities, industry, and all levels of government[29], more research about perceptions is needed and research about the perceptions of underrepresented population groups is especially limited.

Background to the Study: Methods, Participants, and Theoretical Perspectives

Most of the data for this study were collected during the assessment and evaluation of projects sponsored by the National Science Foundation (NSF): Research Experience for Teachers in Hazard Mitigation (RET) and Focus On Retention in Cohorts of Engineering Students (FORCES -S-STEM). Broadening the participation of underrepresented groups in STEM fields is one of NSF's objectives addressed by both of these projects.

Research on the effectiveness of these programs largely stems from the evaluation of the individual grant projects and as such is limited in scope. However, taken together, our data from the separate projects provides insights into the perceptions of multiple groups (teachers, high school students and undergraduates) and shows differences based on gender, (dis)ability, and race/ethnicity. This study expands existing literature in needed areas as outlined in the previous section, and addresses the following questions:

- How do high school and undergraduate students perceive STEM courses and engineering?
- How do perceptions vary according to gender, (dis)ability status, and race/ethnicity?
- What are high school STEM teachers' perceptions about why underrepresented groups remain underrepresented in engineering? How do their perceptions vary according to gender, disability status, and race/ethnicity?

A total of 57 high school STEM teachers and 1247 high school students in STEM courses have been surveyed during the process of collecting assessment data for the RET project. Survey data analysis is supported by data collected from teacher focus groups, classroom observations and teacher-produced materials such as lesson plans and reflective papers. Additional data was collected by surveying undergraduate engineering students; 54 students participated in a survey specifically addressing the perceptions discussed in this paper. In adherence to our ethical commitments and the parameters of using data per our Institutional Review Board protocol, data will be shared obscurely to keep participants and locations anonymous, as well as deter to the extent possible connections among participants and institutions. Participants self-identified their gender, racial/ethnic background, and disabilities as shown in Table 1.

Table 1. Self-Reported Participant Demographic Data

	High School STEM Teachers	High School STEM Students	Undergraduate Engineering Students
Total (n)	57	1247	54
Female	57.9	49.6	20.4
Male	40.4	46.9	77.8
American Indian or Native American	1.8	1.5	1.9
Asian/Pacific Islander	1.8	5.6	18.5
Biracial or Multiracial	3.5	14.3	
Black or African American	5.3	20	13.0
Latino/a or Hispanic	8.8	29.8	
Middle Eastern	3.5	0.4	
South Asian		0.6	
White or Caucasian	75.4	23.6	40.7
Other Ethnic Background			25.9
ADD*	1.8		
Diabetic*	1.8		
Dyslexic*	5.3		
Hearing Impairment	1.8	1.8	5.6
Visual Impairment (other than minor vision correction)		6.4	9.3
Mobility/Orthopedic Impairment		1	
Other Disabilities			3.7

While survey instruments were developed for evaluation of individual projects, this article analyzes data from across the projects to better understand perceived barriers to participation in engineering. The grant teams developed the survey instruments for the RET and S-STEM projects; RET teacher participants provided input on the development of the high school student survey. Survey questions asked teachers and undergraduates why women, minorities, and those with disabilities are underrepresented in the field of engineering and to consider a number of factors. Those factors are listed later in this paper.

* In addition to the federally recognized categories of impairment (hearing, visual, and mobility), surveys allowed participants to write-in other disabilities; these are denoted by an asterisk.

Using a five-point Likert scale ("strongly disagree" to "strongly agree"), high school student participants responded to statements about STEM courses, such as "It seems like Science, Technology, Math and Engineering classes are geared more for boys than girls." High school teachers helped develop appropriate language for the student surveys. These questions shed light on students' perceptions of courses versus fields by gender, race, and (dis)ability.

Likert scales, while limited in various ways, are useful because "they build in a degree of sensitivity and differentiation of response while still generating numbers."[30] To address some of these limitations, data collected also included open-ended questions, focus groups, material artifacts (lesson plans, student-produced work such as websites, reflection papers), and observations. NVivo qualitative software and SNAP online survey software are being used to collect and analyze data. As well, analysis of survey data will consider McCall's cautions in the use of interval scaled scores and suggestions for using percentages and collapsed categories.[31]

Data collection is ongoing; a more thorough (and statistical) analysis of survey data will be conducted and reported in subsequent publications of different studies. However, theories of critical qualitative research[32] provide the prevailing framework for this article. Underrepresented populations in STEM fields primarily refer to Latino/as, African Americans, women and individuals with a legally recognized disability; therefore, this study's analysis reflects critical theories that focus on race, gender, and ability such as Critical Race Theory[33-36]. Qualitative research together with critical theoretical perspectives of difference interrupts empirical inquiry as value-neutral; deconstructs mainstream ideologies that subordinate "others;" and (re)generates methodologies like counter storytelling for academic inquiry.[37] Qualitative inquiry is heterogeneous on purpose. At the end of the day, "assessing the complexity and messiness of practice-in-context is the strength of qualitative research."[38] Thus, rather than conclusions, the information presented here report the data as collected, albeit in small numbers, and include the perceptions of our participants. It is qualified and limited in this way, and further analysis is planned.

Findings

The findings are organized into sections by group: High School STEM Teachers, High School STEM Students, and Undergraduate Engineering Students. For each group, the group's perceptions of barriers for underrepresented populations are discussed. Each group section is organized into three sub-sections according to disability, gender, and race/ethnicity. The conclusion offers some reflections on the findings across groups.

High School STEM Teachers

Using a five-point Likert scale ("strongly disagree" to "strongly agree"), teachers were asked if "making science, technology, engineering, and math lessons more relevant to students who have been traditionally underrepresented in these fields", will encourage such students to pursue careers in science and engineering. Nearly all respondents (98.2%) somewhat agreed or strongly agreed with that statement; no teachers disagreed. Yet, as will be shown below, few teachers indicated that curriculum and instruction were factors in the underrepresentation of such students in the field of engineering.

Teachers also were asked to check all responses with which they agreed for the following questions: (1) In the US, women are underrepresented in the field of engineering because___; (2) In the US, people with disabilities are underrepresented in the field of engineering because___; and (3) In the US, minority people of color, especially African Americans, Latino/as, and American Indians, are underrepresented in the field of engineering because___. They could select from the following factors and they had the option to list other reasons.

- The curriculum fails to consider learner differences.
- Instructional methods fail to consider learner differences.
- They do not have role models in their family.
- They do not have role models that reflect their own identity group(s) in school.
- They are not prepared take the necessary classes (do not have the academic background).
- They prefer to pursue other careers.
- They do not have the self-discipline.
- They lack financial resources.
- They do not put in enough effort.
- Schools do not encourage them.
- Peers influence them.
- They feel that they do not fit-in.
- They are tracked out of the necessary classes.

Perspectives on Persons with Disabilities. Survey results revealed several differences in perspectives between teachers with and without disabilities with regard to why people with disabilities are underrepresented in engineering (Figure 1). While the factor "they feel that they do not fit in" was cited most among both able-bodied teachers and those with disabilities, the fraction of respondents in each group varied by more than 20% (63.5% able-bodied, 40.0% with disabilities). There were a number of factors that able-bodied teachers perceived as contributing to the underrepresentation of people with disabilities that were not cited as factors by any of the teachers with disabilities (e.g. failure of curriculum and instructional methods to consider learner differences). The difference in perspectives regarding the lack of family role models is also notable. While 20.0% of teachers with disabilities cited this as a factor, only 5.8% of able-bodied teachers agreed. The two groups held similar perceptions regarding the impact of factors such as academic preparation, peer influence and being tracked out of the necessary classes; roughly 20.0% to 25.0% of teachers in both groups held these views.

Perspectives on Gender Differences. The four factors that the majority of male teachers perceived as contributing to the underrepresentation of women in engineering are listed in Table 2. Female teacher responses agreed with many of the male responses, but in most cases, to a lesser degree.

It is notable that while the majority of female respondents perceived the lack of encouragement by schools (63.6%) and feeling that they do not fit in (54.5%) as barriers, only 39.1% of male respondents held these views. It is also noteworthy that only a small fraction of teachers, regardless of gender, identified failure of curriculum (12.1% female, 8.1% male) and instructional methods (15.2% female and 13.0% male) to consider learner differences as barriers.

Figure 1. Responses to Why People with Disabilities are Underrepresented in Engineering: Perspectives of High School Teachers with and without Disabilities

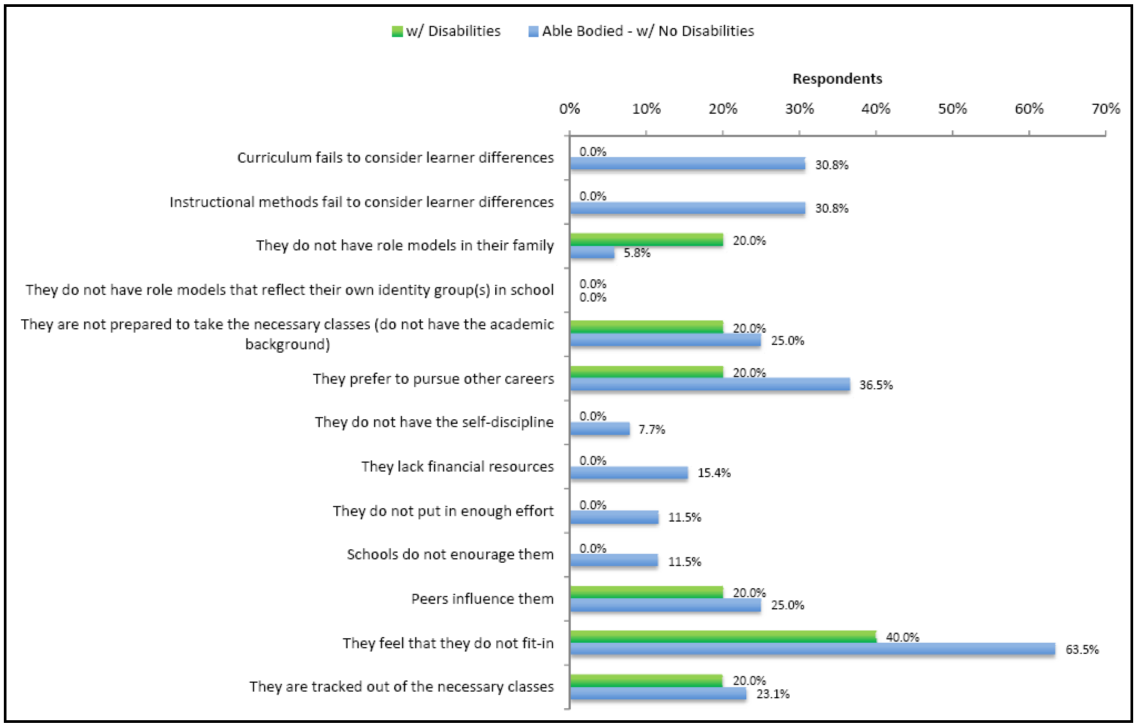
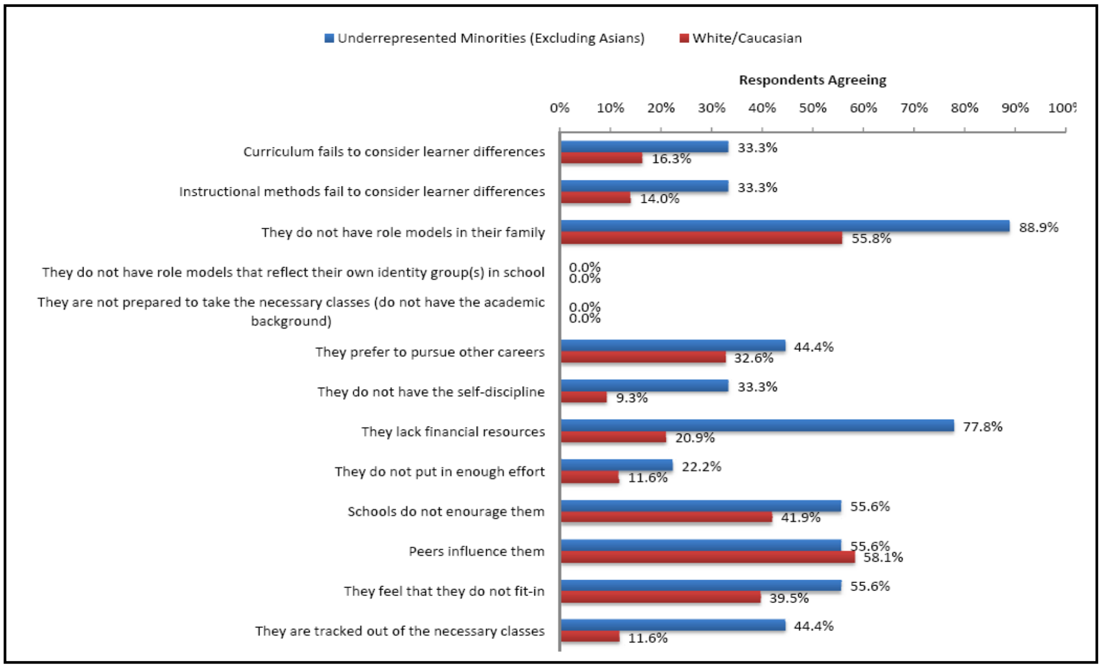


Table 2. Comparison of Gender Perceptions of Barriers to Female Participation in Engineering: Female Versus Male High School Teacher Perspectives

	% of Teachers Identifying Each Barrier	
Survey Item	**Females**	**Males**
Peers influence them	51.5	65.2
They do not have role models in their families	60.9	60.9
They do not have role models that reflect their own identity group(s) in school	54.5	60.9
They prefer to pursue other careers	54.5	60.9

Perspectives on Underrepresented Ethnic Minorities. Figure 2 compares the perceptions of barriers to participation of minorities in engineering from teachers of underrepresented minority groups (Black/African American, Latino/a, Native American) to those of their White/Caucasian counterparts. The vast majority of minority teachers identified the lack of role models in the family (88.9%) and lack of financial resources (77.8%) as barriers. On the contrary, only 55.8% and 20.9% of White/Caucasian respondents, respectively, held the same views. Only two factors were identified by the majority of White/Caucasian teachers as barriers to minority participation – lack of role models in the family (55.8%) and peer influence (58.1%). The majority of minority teachers identify the factors mentioned above, as well as others. For example, they indidicated as barriers that schools do not encourage them (55.6%) and 55.6% that they feel they do not fit in (55.6%).

Figure 2. Responses to Why Minorities are Underrepresented in Engineering by Ethnicity: Perspectives of Underrepresented Minority High School Teachers versus Whites/Caucasians



While smaller fractions of minority teachers identify external factors such as being tracked out of the necessary classes (44.4%) and failure of curriculum and instructional methods to consider learner differences (33.3% each), the responses indicate that these perceived barriers are more important to minority teachers who were surveyed. In contrast, only half the fraction of White/Caucasian teachers surveyed identified those factors as barriers. Of the internal factors, minority teachers cited lack of self discipline (33.3%) and effort (22.2%) as barriers while substantially lower fractions of White/Caucasian respondents held those views (9.3% and 11.6%, respectively).

High School STEM Students

High school students were surveyed regarding their interest in engineering majors and STEM majors in general, as well as their self assessment of math and science capabilities. They were also asked the degree to which they agreed or disagreed with statements related to the underrepresentation of females, minorities and people with disabilities in engineering.

Perspectives on Persons with Disabilities. Larger fractions of able-bodied students indicated STEM fields as intended majors of study (55.3%) compared to students with disabilities (37.8%). The difference between the groups was smaller when asked how strongly they agreed or disagreed with the statement "Before I entered this class, I was interested in pursuing a degree in engineering," with 20.4% and 24.1% of students with and without disabilities, respectively, agreeing or strongly agreeing (Table 3). Responses to the statement "I enjoy science and math classes" reflect the differences between the groups' responses regarding intended majors, with

44.9% and 63.0% of students with and without disabilities, respectively, agreeing or strongly agreeing.

Table 3. Comparisons of Perceptions between High School Students with Disabilities and Able-bodied Students

	% of Students who Strongly Agree/Somewhat Agree	
Survey Item	With Disabilities	Without Disabilities
Before I entered this class, I was interested in pursuing a degree in engineering.	20.4	24.1
I usually earn grades of "A" and "B" in science and math classes.	48.0	71.6
I enjoy science and math classes.	44.9	63.0
It seems like STEM classes are geared more for able-bodied students, rather than students with disabilities.	26.5	27.2

Both able-bodied students and those with disabilities held similar perceptions about STEM courses being geared more for able-bodied students rather than students with disabilities. A total of 26.5% and 27.2% of students with and without disabilities agreed or strongly agreed that this was the case.

Perspectives on Gender Differences. While the fraction of males that agreed or strongly agreed with the statement "Before I entered this class, I was interested in pursuing a degree in engineering" is roughly three times the fraction of females responding positively to this statement (35.6% versus 12.1%), both groups show the same level of self-reported performance and enjoyment of science and math. The majority of both male and female students (66.8% and 69.4%, respectively) stated that they usually earn grades of "A" and "B" in science and math courses and that they enjoy science and math classes (56.1% and 66.0%, respectively). Thus, female math and science capabilities and enjoyment of the subjects are not being translated to their intended majors according to this data. Roughly one fourth of both groups of students believed that STEM classes are geared more for boys than for girls.

Table 4. Comparisons of Perceptions between Female and Male High School Students

	% of Students who Strongly Agree/Somewhat Agree	
Survey Item	Females	Males
Before I entered this class, I was interested in pursuing a degree in engineering.	12.1	35.6
I usually earn grades of "A" and "B" in science and math classes.	69.4	66.8
I enjoy science and math classes.	56.1	66.0
It seems like STEM classes are geared more for boys than girls.	26.1	25.5

Perspectives on Underrepresented Minorities. Large fractions of both underrepresented minorities and White/Caucasian students indicated STEM fields as intended areas of study (47.4% and 57.5%, respectively – Table 5). Likewise, both groups indicated that they enjoy (57.5% and 67.0%, respectively) and earn "As" and "Bs" in science and math classes (62.3% and 78.6%, respectively). Less than 30% of both groups showed an interest in engineering majors prior to enrolling in the class in which the survey was administered; nearly equal fractions stated that the class inspired them to pursue a degree in a STEM field (38.9% of minorities and 36.4% of Whites/Caucasians).

Table 5. Comparisons of Perceptions between Female and Male High School Students

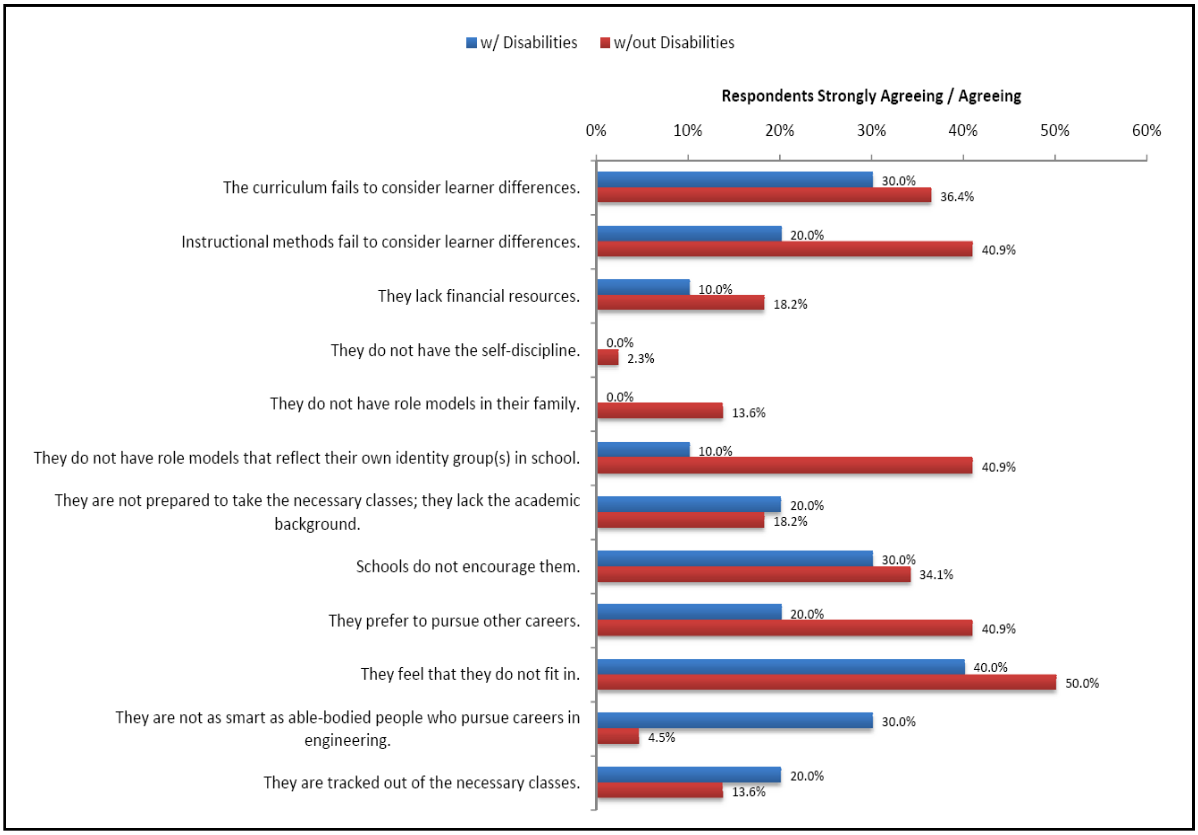
	% of Students who Strongly Agree/Somewhat Agree	
Survey Item	Minorities	Whites/Caucasians
Before I entered this class, I was interested in pursuing a degree in engineering.	20.7	28.6
I usually earn grades of "A" and "B" in science and math classes.	62.3	78.6
I enjoy science and math classes.	57.5	67.0
It seems like STEM classes are geared more for Whites, rather than students of color.	16.4	9.5

Undergraduate Engineering Students

Undergraduates were asked the degree to which they agreed or disagreed with statements regarding the underrepresentation of women, minorities and people with disabilities in engineering. The factors they were asked to consider were essentially the same as those listed in the high school teachers' survey. Responses were collected using a four-point Likert scale ("strongly agree" to "strongly disagree"); there was no "neutral" response.

Perspectives on Persons with Disabilities. The most widely help perception among engineering undergraduates with regard to the underrepresentation of persons with disabilities in engineering is that they feel they do not fit in (Figure 3). A total of 40.0% of students with disabilities and 50.0% of able-bodied students agreed or strongly agreed with this factor. There was agreement between the two groups in their views of factors such as curriculum failure to consider learner differences (30.0% and 36.4% of students with and without disabilities, respectively) and the lack of encouragement from schools (30.0% and 34.1% of students with and without disabilities, respectively). The largest discrepancy was with the factor "they are not as smart as able-bodied people who pursue careers in engineering." Surprisingly, nearly one third (30.0%) of students with disabilities strongly agreed or agreed with this statement, whereas very few able-bodied students concurred (4.5%), which raises questions regarding self-efficacy among the disabled students with regard to their perceived aptitudes in STEM fields. Other areas of disagreement between the two groups were related to the lack of role models that reflected their own identity groups in school and failure of instructional methods to consider learner differences. A total of 40.9% of able-bodied undergraduate engineering students viewed these factors as important, whereas only 10.0% and 20.0% of students with disabilities agreed/strongly agreed, respectively.

Figure 3. Undergraduate Engineering Student Responses to Why People with Disabilities are Underrepresented in Engineering



Perspectives on Gender Differences. The majority of both female and male undergraduate engineering students agreed or strongly agreed that females are underrepresented in engineering because they prefer to pursue other careers (72.2% of females and 64.3% of males – Figure 4). An equally large fraction of female respondents also perceived "they feel that they do not fit in" as a barrier (63.9%). This reflects the culture of many engineering colleges and firms, despite the intention and efforts of many to diversify their student enrollment and workforce, respectively. To degrees of varying success, some colleges and firms have diversified. By comparison, 35.7% of male respondents agreed or strongly agreed with that statement.
The lack of role models in schools was cited by nearly half (45.4%) of the females and slightly more than one quarter (28.6%) of the males as an important factor. There were three views that only male respondents held regarding the underrepresentation of women in engineering:

- The curriculum fails to consider learner differences (26.2%).
- They are not prepared to take the necessary classes; they lack the academic background (7.1%).
- They are not as smart as males who pursue careers in engineering (9.5%).

It is interesting to note that while the last two perceptions (which are held by nearly 10% of male respondents) reflect a perceived lack of preparation and aptitude of women for engineering majors/careers, data collected from the university's Institutional Research office for 300 College of Engineering first time freshmen in Fall 2009 (as a part of another study) reflect the following facts:

- A larger fraction of females students than male students was calculus-ready for their first fall semester (57.5% versus 40.8% enrolled in Calculus I or higher).
- Average SAT Math scores for both groups were equal (590).
- A slightly larger fraction of female students was retained in engineering through the first year compared to the fraction of male students retained (50.0% versus 46.5%).

Perspectives on Underrepresented Minorities. As shown in Figure 5, White/Caucasian undergraduate engineering students mostly perceived the factor "they prefer to pursue other careers" as a barrier to minority participation in engineering (58.8%). While a large fraction of minority students agreed or strongly agreed with that statement (41.7%), they mostly identified the lack of financial resources as a barrier (50.0%). By comparison, only 17.6% of their White/Caucasian counterparts concurred. There are similar differences in perceptions between the two groups with regard to the factor "they feel that they do not fit in" (41.7% versus 17.6%). As with female students, this points to the historical culture of engineering colleges and places of employment.

Figure 4. Responses to Why Women are Underrepresented in Engineering: Perspectives of Female and Male Engineering Undergraduates

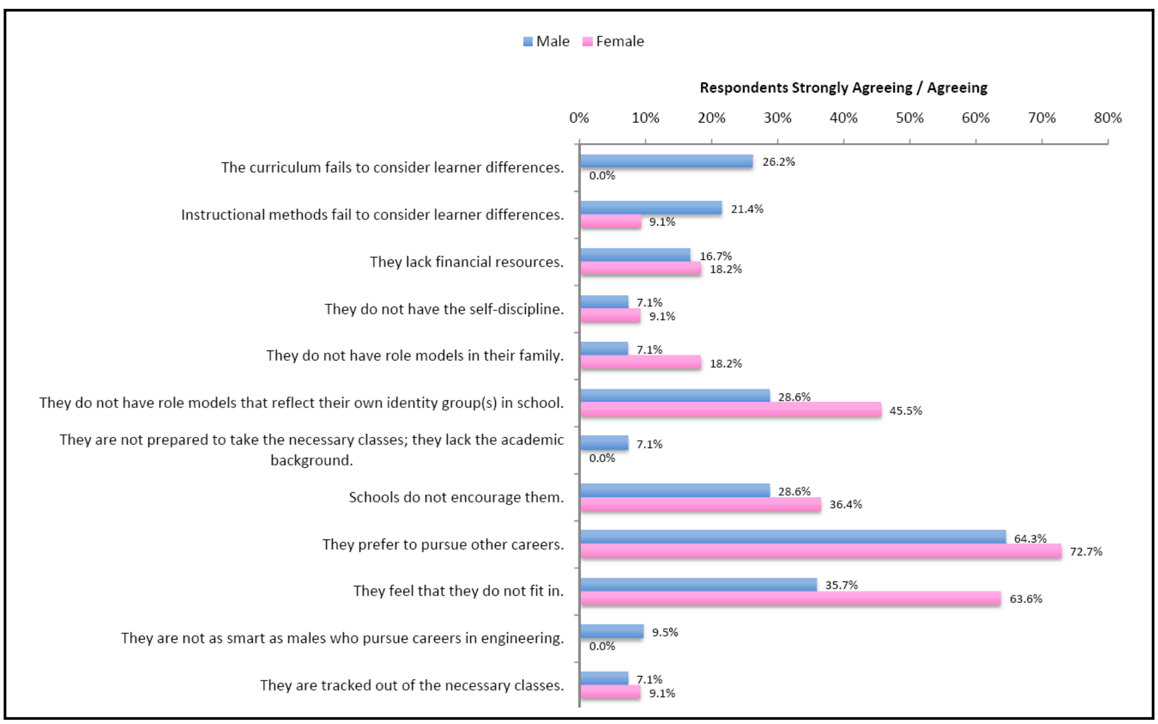
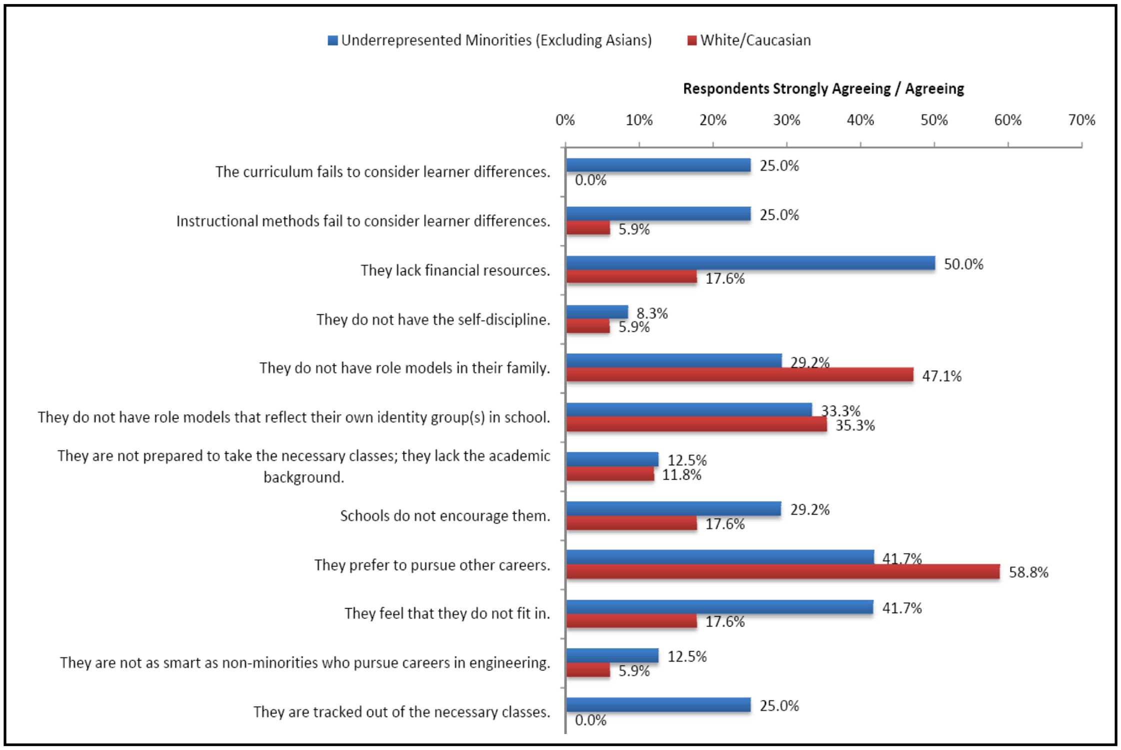


Figure 5. Responses to Why Minorities are Underrepresented in Engineering: Perspectives by Ethnicity/Race



One quarter of minority respondents perceived each of the following as barriers, while White/Caucasian students largely did not:

- The curriculum fails to consider learner differences (25% versus 0%).
- Instructional methods fail to consider learner differences (25% versus 5.9%).
- They are tracked out of the necessary classes (25% versus 0%).

Efforts to diversify curriculum and instruction (such as, culturally responsive[39] and relevant[40] pedagogy, multicultural education[41]) have waxed and waned over time. While the results of these efforts varies, our data in part corroborates other work that argues curriculum and instruction continue to reflect to varying degrees a mainstream student-subject[42] and official knowledge[43] (e.g. subjects and knowledges based on preconceived norms of so-called White, middle-class, heterosexual, able-bodied males).

A small fraction of students reflected perceptions that minority students are not as smart as non-minorities who pursue careers in engineering. As was the case for students with disabilities, the fraction of minority students who held this view was larger than the fraction of White/Caucasian students (12.5% versus 5.9%). This suggests that self-efficacy among minority students be examined and addressed.

Reflections Across Groups: Summary of Observations and Implications for Further Study

In three sections below some themes in the data that appear across groups are discussed. This section is not a complete comparative analysis of the three groups and sub-sections described above. Nor is the discussion presented in each section exhaustive, as each might warrant its own full-length paper. Rather, the reflections provided might better be considered jumping-off-places for future and more in-depth analysis.

Reflections on the Failure of Curriculum and Instructional Methods

For several reasons it is noteworthy that teachers generally did not cite curriculum and instructional methods as barriers to diversifying STEM education and careers. First, arguably teachers have the most control over shaping these two areas. Second, their students at least to some degree felt that their STEM courses were geared more for mainstream students than underrepresented groups. And third, bias in curriculum and instruction is well-documented in the literature that practicing teachers should be aware of.[44] This preliminary analysis raises an important question. If teachers fail to see curriculum and instruction as biased and as barriers to diversifying STEM education and fields, then how can they meet the needs of populations traditionally underrepresented in STEM education and fields?

It is not surprising that students from underrepresented groups tended to view curriculum and instruction as barriers more than their mainstream counterparts. Researchers have argued that curriculum and instructor have a subject. For example, Ellsworth's research asks, who does the curriculum think the student is?[45] And Brauer and Clark ask: "What does the curriculum think the text is? In what ways are texts presumed to represent their subjects, and for what purposes?[46] When put in conversation with relevant literature, this finding suggests that students do not see themselves reflected in the course.

Reflections on Gender Differences

Both teachers and undergraduates indicate that females are underrepresented in engineering because they prefer to pursue other careers. However, preferences and choices, while partially self-determined, are also shaped by background and experiences. For example, students may be tracked in or out of science by the socio-contextual power dynamics of school and society that mediates attitudes, values, and decision-making. Oaks' (1990) report *Lost Talent: The Underparticipation of Women, Minorities, and Disabled Person* began laying the groundwork for how such dynamics shape the PreK-16-graduate school "pipeline" for those who are not traditionally represented in science and math and imagined as science/math majors, scientists, and mathematicians.[47] In the American Association of University Women's recent report *Why So Few?: Women in Science Technology Math and Engineering*, Hill, Corbett, and Rose outline the ongoing effects of "societal beliefs and the learning environment on girls' achievements and interest in science and math."[48]

In addition, while females and males indicated similar abilities to earn "As" and "Bs" in science and math and that they enjoy these classes, about three times more males than females indicated their interest in pursuing an engineering career. This finding echoes other research that posits students' decisions to pursue, and persist in, engineering are more due to their perceptions (e.g.

about institutional culture and engineering careers), which differ across gender and ethnicity, and not because male and female students differ academically.[49-51]

Reflections on Self-Perceptions of Underrepresented Groups

Similar to the way in which preferences are both self-determined and shaped, our identities (as student-subjects, engineer-subjects, minority-subjects, (dis)abled-subjects, teacher-subjects) also are constructed. Research has shown that subjects internalize identities, including mainstream norms and negative perceptions of those who do not fit mainstream gender, race, and ability norms.[51-2] Our data indicates the ongoing need to help students understand identity construction and debunk preconceived myths.

While there are similarities of perceived barriers among participants surveyed (e.g. high school STEM students, high school STEM teachers, and engineering undergraduates), the analysis of our data shows that perceptions are not uniform among participants, but rather that they perceive curricula, instruction, student differences, engineering, and engineers differently. Our data suggests that approaches to diversifying engineering need to consider perceptions, as well as be multipronged and differentiated. This paper reflects the data we collected, albeit in small numbers, and includes the perceptions of our participants. It is qualified and limited in this way, and further analysis is planned. These reflections are best understood when situated within the relevant, current literature and methodology that we provide.

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