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Latinx and Caucasian Elementary School Children's Knowledge of and Interest in Engineering Activities

Gamze Ozogul

Indiana University, gozogul@indiana.edu

Cindy Faith Miller

Arizona State University, Cindy.F.Miller@asu.edu

Martin Reisslein

Arizona State University, reisslein@asu.edu

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Abstract

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Keywords

elementary school students, engineering interest, engineering occupational knowledge, ethnicity, gender

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Gamze Ozogul,¹ Cindy Faith Miller,² and Martin Reisslein²

¹Indiana University
²Arizona State University

Abstract

Ethnic minorities, such as Latinx people of Hispanic or Latino origin, and women earn fewer engineering degrees than Caucasians and men. With shifting population dynamics and high demands for a technically qualified workforce, it is important to achieve broad participation in the engineering workforce by all ethnicities and both genders. Previous research has examined the knowledge of and interest in engineering among students in grades five and higher. In contrast, the present study examined elementary school students in grades K–5. The study found that older students in grades 4 and 5 had both greater knowledge of engineering occupational activities and greater interest in engineering than younger students in grades K–3. Moreover, Caucasian students had greater knowledge and interest levels than Latinx students. There were no significant differences between boys and girls, nor any significant interactions among gender, grade level, and ethnicity. A significant positive correlation between knowledge of engineering occupational activities and interest in engineering was also found. The findings suggest that early engineering outreach interventions are important. Such early interventions could potentially contribute to preserving the equivalent interest levels of males and females for engineering as students grow older. Also, ethnic disparities in engineering knowledge and interest could potentially be mitigated through early interventions.

Keywords: elementary school students, engineering interest, engineering occupational knowledge, ethnicity, gender

Introduction

There has been increasing concern in recent years regarding the low percentage of adults who are earning degrees and pursuing careers in engineering (NAE, 2011; U.S. Congress Joint Economic Committee, 2012). While the number of engineering positions is projected to grow significantly over the next several years, many of these positions are expected to be unfilled due to a shortage of skilled workers (My College Options & STEMconnector, 2012). The low numbers of female and ethnic minority individuals pursuing engineering in U.S. colleges is believed to be a major contributor to the inability to meet the demands of the engineering workforce. At the bachelor level, women and ethnic minority students earn less than 20% and 13% of the degrees awarded in engineering, respectively (NSF, 2015), are less likely to pursue science or engineering majors at the start of college, and are less likely to remain in these fields (U.S. Census Bureau, 2013).

At the same time, a large shift in the ethnic make-up of the U.S. population is unfolding. The U.S. Census Bureau reports that Hispanics and Latinos are the third fastest growing population; projected numbers are to increase from 55 million in 2014 to 119 million in 2060, and by the year 2060, 29% of the U.S. population is projected to be of Hispanic or Latino origin (Colby & Ortman, 2015). For brevity, we use the term “Latinx” to refer to people of Hispanic or Latino origin throughout this article.

Given the underrepresentation of ethnic minorities in engineering (Garrison, 2013) and the increasing proportion of ethnic minorities in the U.S. population, it is highly important to examine the development of attitudes of various ethnicities and both genders toward engineering (Chachra, Kilgore, Loshbaugh, McCain, & Chen, 2008). As reviewed in the next subsections, research has found gender and ethnic differences in children's engineering attitudes. However, we do not know exactly at what age these attitudes and lack of interest in or knowledge of engineering occupations become apparent. Therefore, this research investigates K–5 Latinx and Caucasian students' interest in and knowledge of engineering occupational activities, and how their interest in and knowledge of engineering relates to age and ethnicity.

While there are likely many factors that contribute to the gender and ethnic disparities in engineering, social and developmental psychologists have focused on children's interests and perceptions. Prior research has found gender and ethnic differences in children's interest in engineering as early as in middle and high school (Aschbacher, Li, & Roth, 2010; Degenhart et al., 2007). To our knowledge, however, prior research has not explored if these discrepancies begin as early as elementary school. Moreover, little research has explored the role of children's knowledge of the engineering field and how it may contribute to their interest in engineering. In the present study, we address these open research areas.

The Importance of Early Exposure to Engineering

This study focuses on knowledge about engineering occupations and interest in engineering in elementary school children (and does not consider engineering skills development or learning). In order to position this study in the wider context of the early exposure to engineering, we briefly review the existing research on the effects of early exposure to engineering on the broad spectrum of child characteristics, spanning from skill development and learning to interest.

Research findings in developmental psychology and neurobiology have revealed strong effects of the early environment on the capacity for human skill development. Early experiences have uniquely powerful influences on the development of cognitive and social skills, as well as on shaping the brain architecture. This is because the capacity for changes in the foundations of human skill development and neural circuitry is highest early in life (Knudsen, Heckman, Cameron, & Shonkoff, 2006). Early learning opportunities appear to enhance children's capacity to learn, which may improve their later elementary school performance (Burger, 2010).

Research has shown that interest in science is usually ignited before middle school, and that early exposure to information is instrumental in motivating students to develop their talents to pursue science as a career option (Maltese & Tai, 2010; Rogers, Wendell, & Foster, 2010). Most

conceptualizations of individual interest include positive emotion, affect, or feelings (Hidi & Renninger, 2006; Krapp, 2007), and include perceived value judgement for the content being taught (Eccles & Wigfield, 2002; Hidi & Renninger, 2006). Johnson, Ozogul, DiDonato, and Reisslein (2013) presented a multimedia overview of engineering occupations to a total of 565 students ranging from elementary to high school. They concluded that early exposure to such engineering overviews, as early as in grades 3–5, has a more pronounced positive impact on engineering perceptions than exposure at higher grade levels. Similarly, in a longitudinal study investigating 10-year-olds' interest in science and scientific careers, Archer et al. (2010) found over a period of five years that beneath the broadly expressed general enthusiasm for science by these children (independent of gender, ethnicity, and social class), the development of gender, ethnic, and class distinctions solidified in later years. Taken together, these findings indicate that it is very important to start exposure to engineering early, before these perceptions begin their solidification in children.

Given that learning develops in a cumulative manner, in that early experiences have a profound effect on later skill development and one's motivation to learn (Heckman, 2006), it is essential to understand children's early beliefs and experiences if we want to change occupational disparities in science, technology, engineering, and mathematics (STEM) fields in the long term. However, gaps in early cognitive proficiencies of children are evident across social class and ethnic groups, as children enter kindergarten (Loeb, Bridges, Bassok, Fuller, & Rumberger, 2007). For example, English-proficient Latinx five-year-olds in California score about 0.38 of a standard deviation (SD), or about three months, behind White counterparts in pre-reading and math skills (Rumberger & Arellano, 2003). Martin, Simmons, and Yu (2013) investigated factors that contributed to Latinx women choosing an engineering career in college. They found that delays in the recognition or identification of resources for succeeding in STEM fields resulted in complications in the transitions of the Latinx women to university courses. Thus, early provisioning and awareness of resources appear to be important for successful engineering studies.

Gender and Ethnic Differences in Engineering Perceptions

Prior research investigating ethnic and gender differences in engineering stereotypes and beliefs has generally focused on middle school, high school, and college-age subjects (e.g., Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Brainard & Carlin, 1998; Chan, Stafford, Klawe, & Chen, 2000; Ing, Aschbacher, & Tsai, 2014; Salzman, Ohland, & Cardella, 2015; Schaefer, Epperson, & Nauta, 1997; Tolbert & Cardella, 2016). These studies on students of middle school age and older consistently found that there are differences in students' attitudes and perceptions based on gender: female students have more negative attitudes

toward engineering than male students, and female students enter engineering careers with lower confidence in their engineering knowledge and abilities compared to their male counterparts. However, we do not know when children first develop gender and/or ethnic stereotypes about engineering, and if and how this knowledge may be related to their competency beliefs.

While elementary school students' stereotypes and achievement-related beliefs regarding math and science are well studied, there is little research that explores the development of engineering perceptions in this age group (Lachapelle, Phadnis, Hertel, & Cunningham, 2012; Lindberg, Pinelli, & Batterson, 2008). For instance, only a few studies have examined engineering attitudes of students of grade five or higher (DiDonato, Johnson, & Reisslein, 2014; Gibbons, Hirsch, Kimmel, Rockland, & Bloom, 2004; Guzey, Harwell, & Moore, 2014; Hutchinson, Bodner, & Bryan, 2011; Strutz, 2010; Wendell & Rogers, 2013; Wright & Terry, 2010). However, there is very limited understanding of the development of these attitudes in the earlier elementary school years K–5. To the best of our knowledge, there has not been a study that examined gender and ethnic differences in elementary school students' engineering interests and their knowledge of the engineering field.

Knowledge of Engineering Career Field in Early Grades

There have been only a few studies on students' knowledge of engineering occupations. For elementary school students, Lachapelle et al. (2012) found that students' knowledge of engineering is generally more focused on engineers repairing or installing things, such as cars or electrical items, rather than on engineers improving or inventing things. Lachapelle and Cunningham (2007) focused on the knowledge of engineering of students in grades 2–6, and found that through implementation of an engineering curriculum, the students significantly improved their understanding of the engineering and technology fields, compared to the control group. Cunningham, Lachapelle, and Lingren-Streicher (2005) investigated the perceptions of students in grades 1–5 toward what engineers do. Results showed that most of the students indicated that engineers repair cars (78.4%), install wiring (75.2%), drive machines (70.7%), construct buildings (69.7%), set up factories (67.1%), and improve machines (63.5%). That is, students strongly confuse construction workers and auto mechanics with engineers.

For middle school students, Hirsch, Berliner-Heyman, Kimmel, and Carpinelli (2011) found a man fixing a car or driving a train to be the most common misconception of an engineer. Also, students frequently represented an engineer as a person alone with a computer, which is another common misconception of engineers spending time alone while working. Other studies on the knowledge of the engineering field have focused on students in high school

(Montfort, Brown, & Whritenour, 2013), college freshmen (Chacra et al., 2008; Pritchard & Mina, 2013), and engineering faculty (Pawley, 2009). To the best of our knowledge, no prior study has focused on gender and ethnic differences in elementary school students' attitudes toward and knowledge of engineering. The misconceptions about engineering found by Hirsch et al. (2011), Cunningham et al. (2005), and Lachapelle et al. (2012) may contribute to the gender and ethnic differences in engineering attitudes and participation. Possibly, correct knowledge about engineering may help alleviate the gender and ethnic differences.

Engineering Education in Elementary Schools

Engineering education in elementary schools is generally a nascent area (Cunningham, Knight, Carlsen, & Kelly, 2007; Lachapelle & Cunningham, 2014; Moore et al., 2014; Sun & Strobel, 2013) even though the engineering field has the advantage in elementary schools of being something students enjoy, as it involves hands-on work and creativity (Portsmore & Rogers, 2004). In order to advance the technological fluency of the youth, the implementation of science and engineering curricula should start in early grades. Also, there needs to be a reexamination of the content that young children are able to learn, in particular in the engineering areas (Bers, 2010).

A few studies have examined the perspectives of elementary school teachers on engineering education (Capobianco, Ji, & French, 2015; Dalvi & Wendell, 2017; Hsu, Purzer, & Cardella, 2011; Lottero-Perdue, & Parry, 2016; Moffett, Weis, & Banilower, 2011; Wendell, 2014; Yoon, Evans, & Strobel, 2014). However, relatively few studies have examined engineering education at the elementary school age (Purzer, Strobel, & Cardella, 2014). In particular, elementary school engineering education in formal settings has been considered (Aguirre-Muñoz & Pantoya, 2016; Barth, 2013; Johnson, Wendell, & Watkins, 2016; Jordan & McDaniel, 2014; Koerber, Mayer, Osterhaus, Schwippert, & Sodian, 2015; Lachapelle & Cunningham, 2016; Milto, et al., 2016; Strawhacker, Sullivan, & Portsmore, 2016; Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux, 2011; Wendell & Rogers, 2013; Wendell, Watkins, & Johnson, 2016), while informal settings have also been examined (Dalvi & Wendell, 2015; Dorie, Cardella, & Svarovsky, 2015; Frey & Powers, 2012; Portsmore & Swenson, 2012).

A few studies have examined the integration of engineering education into elementary schools by using it as a context for teaching science (Cejka, Rogers, & Portsmore, 2006; Donna, 2012; Kazakoff, Sullivan, & Bers, 2013; Marulcu, 2014; Marulcu & Barnett, 2013; Schnittka, 2012; Stohlmann, Moore, & Roehrig, 2012; Wang, Moore, Roehrig, & Park, 2011; Wendell & Lee, 2010; Yoon, Dyehouse, Lucietto, Diefes-Dux, & Capobianco, 2014). These studies generally found that elementary school students' knowledge of the content of a specific engineering project increased after

the implementation of the programs, and that positive responses to engineering increased. However, even with these interventions, we still know little about elementary school children's understanding of engineering occupational fields as a result of engaging in these engineering activities.

Even if these types of interventions create interest toward a certain engineering activity, they do not necessarily expose students to the knowledge and understanding of broad engineering career options. Many career options are never considered by certain gender and ethnic groups because the individual is unaware of their existence, has little opportunity or encouragement, or has inaccurate information regarding the career itself or the individual's potential (self-efficacy) for being successful in that field (Eccles, 2005). Another issue that has motivated the present study is that little research has examined the role of students' knowledge of occupational STEM activities, and this is especially relevant for engineering (Lachapelle et al., 2012). Unlike other STEM fields, students are rarely exposed to engineering occupational fields in elementary school (Carr, Bennett, & Strobel, 2012). Therefore, it is unclear when students develop an understanding of and interest in engineering, how this may relate to gender and ethnicity, and whether knowledge of and interest in engineering are related.

Investigating students' engineering knowledge and beliefs in early elementary school is essential for the development of comprehensive, developmentally appropriate, and culturally responsive interventions (Gay, 2010). There is a concern about the achievement gaps across different demographic groups, especially women and Latinx students. If these disparities were corrected then the United States would be better able to fulfill the increasing demand for STEM workers (U.S. Congress Joint Economic Committee, 2012).

Present Study

Considering the gender and ethnic discrepancies apparent in the current engineering workforce, and the projected growth of the Latinx population in the future, a focused investigation is necessary to understand contributing factors for this divide, and to understand how early this divide starts. Thus, the present study focuses on exploring knowledge of and interest in engineering of K–5 students. More specifically, this study examines the *knowledge* of engineering from two angles: actual knowledge, as assessed through a Knowledge of Occupational Activities Measure–Engineers (KOAM–E), as well as perceived knowledge, as self-reported by the students. Moreover, the study examines the students' self-reported *interest* in engineering. In particular, this study seeks to address the following research questions related to the knowledge of engineering and interest in engineering:

1. Actual engineering occupational knowledge (KOAM–E)
 - a. Are there grade level differences, gender differences, and ethnic differences in the overall engineering

occupational knowledge between Caucasian and Latinx children?

- b. Do grade level, gender, and ethnic (Caucasian vs. Latinx) differences in children's engineering knowledge depend on the engineering domain (civil, mechanical, electrical/computer)?
2. Perceived knowledge of engineering occupational activities
 - a. Are there grade level, gender, and ethnic (Caucasian vs. Latinx) differences in children's perceived knowledge of engineers?
 - b. Is there an association between children's actual knowledge of occupational engineering activities and their perceived knowledge of engineers?
 3. Interest in engineering
 - a. Are there grade level, gender, and ethnic (Caucasian vs. Latinx) differences in children's interest in engineering activities?
 - b. Is there an association between children's knowledge of occupational engineering activities and their interest in engineering activities?

Method

Participants

Participants were 152 Caucasian/White (54% female) and 167 Hispanic/Latino (50% female) children who were recruited from two public elementary schools, one in the Southwestern USA and one in the Midwestern USA. Children were divided into three grade groups: early (kindergarten and 1st grade; $n = 96$); middle (2nd and 3rd grade; $n = 108$); and upper (4th and 5th grade; $n = 115$). The mean ages in years for the three groups were as follows: $M = 6.21$ ($SD = 0.75$), $M = 8.09$ ($SD = 0.69$), and $M = 10.10$ ($SD = 0.69$), respectively. Only children who received written parental consent and who provided verbal assent participated in this study.

Procedure

Exactly the same procedure was used for both elementary schools. The research material consisted of a paper-pencil survey sheet. Consent forms were distributed to parents to be filled and returned prior to the study. On the day of the data collection, three researchers visited the school sites, and were given a set schedule for visiting the classrooms within the respective elementary school. Prior to completing the survey, students were instructed on how to complete the survey (e.g., using the rating scales) and given opportunities to practice answering neutral survey prompts, such as "I like ice cream." Due to the students'

young age and reading levels for K–2, the researchers divided each class into three small groups, read the questions aloud, and had the students progress through the survey form in groups. For grades 3–5, students were given the survey and asked to fill it out on their own; researchers walked around the room to respond to student questions and ensure students were on task.

All students completed the survey during class time, by marking it with a pencil on the actual survey form. Completing the surveys took approximately 15 minutes in grades K–2, and approximately 10 minutes in grades 3–5. The first section of the survey asked about students' interest toward engineering, the second part of the survey asked about knowledge of engineering activities, and the last part of the survey collected demographic information. Once the surveys were filled, they were collected by the researchers. Students were provided with opportunities to ask the researchers questions, and given a university-labeled pencil as compensation for their participation.

Measures

Actual Knowledge of Engineering Occupational Activities

To capture children's actual knowledge of the occupational activities associated with engineering, we developed the KOAM–E measure. The measure consisted of a list of 13 occupational activities and asked children to circle the activities that describe engineers. The list consisted of six engineering and seven filler (e.g., paint houses) activities. Of the six engineering items, two were associated with civil engineering (plan bridges and canals, build tunnels), two with mechanical engineering (make plans for roller coasters, build robots), and two with electrical/computer engineering (design heart monitors, write computer programs). The construct validity of the KOAM–E measure had been verified with the judgement of subject matter experts (Aiken, 1997). Moreover, we cross-checked the items with occupational data from the U.S. Department of Labor/Employment and Training Administration's Occupational Information Network (O*NET; Peterson et al., 2001). In terms of internal reliability, the Cronbach's alpha for the six engineering items is 0.67 and the Cronbach's alpha for the seven filler items is 0.80. We acknowledge the limitation that the Cronbach's alpha for the six engineering items is relatively low, which may be due to the three different engineering disciplines covered by the six engineering items. We also acknowledge that more research needs to be conducted to assess the psychometric properties of the KOAM–E measure, and generally for measures relating to engineering for young students.

Overall knowledge scores on this measure reflected the total number of correct items (0–13); students received one point for each engineering item they circled and one point for each filler item they left blank. For the three domain scores, children received a score reflecting the number of domain items that they circled (0–2 for each domain).

Perceived Knowledge of Engineering

Occupational Activities

To assess children's perceived knowledge of engineering occupational activities, they were asked to rate how much they know about engineers ("I know what engineers do") on a 0 (*not at all*) to 2 (*yes, a lot*) scale.

Interest in Engineering

Children's interest in engineering was assessed with two items ("I would like to learn about engineers" and "I would like to do engineering activities"). Children were asked to rate both items on a 0 (*not at all*) to 2 (*yes, a lot*) scale. The two interest items were significantly correlated ($r = 0.41, p < 0.001$); therefore, an overall engineering interest score was calculated by averaging the ratings for the two items.

Demographic Information

Demographic information was collected via children selecting their gender (*male* or *female*) and ethnicity (*African American/Black, Asian American, Caucasian/White, Hispanic/Latino, Native American, or Other*) at the end of the questionnaire. Only students who indicated either "Caucasian/White" (35% of the sample) or "Hispanic/Latino" (38.5% of the sample) were included in this study; for brevity, we henceforth use the terms "Caucasian" and "Latinx."

Results

Preliminary Analyses

Initial analyses were conducted to examine normality of the six outcome variables included in this study (overall civil, mechanical, and electrical/computer knowledge, perceived knowledge, and interest). While the knowledge variables were all within the normal range, interest was negatively skewed; thus, this variable was normalized using an inverse transformation. To examine differences by school location, independent sample *t*-tests were conducted on children's knowledge and interest scores. Analyses revealed significant differences for all variables except perceived knowledge: overall knowledge, $t(317) = -7.77, p < 0.001$; civil knowledge, $t(317) = -2.64, p = 0.009$; mechanical knowledge, $t(317) = -3.05, p = 0.002$; electrical/computer knowledge, $t(317) = -3.24, p = 0.001$; perceived knowledge, $t(317) = -1.12, p = 0.264$; interest, $t(317) = -2.81, p = 0.005$. To account for school effects, school location was included as a covariate.

Actual Knowledge of Engineering Occupational Activities

To examine grade level, gender, and ethnic differences in children's overall engineering occupational knowledge (Research Question 1), a 2 (gender) \times 2 (ethnicity) \times 3 (grade) ANCOVA was conducted with school location as a

covariate. The main effect for gender was marginally significant, $F(1, 306) = 2.78, p = 0.097$, suggesting that, overall, boys ($M = 8.50, SD = 2.41$) had slightly more knowledge of occupational engineering activities than girls ($M = 8.35, SD = 2.41$). Results also revealed significant main effects for both ethnicity, $F(1, 306) = 6.45, p = 0.012$, and grade, $F(2, 306) = 50.23, p < 0.001$. For ethnicity, findings indicated that Caucasian students ($M = 9.27, SD = 2.38$) demonstrated more knowledge of engineering occupational activities than Latinx students ($M = 7.65, SD = 2.18$). For grade, post hoc tests using a Bonferroni adjustment for multiple comparisons indicated that 4th/5th graders ($M = 9.97, SD = 2.11$) displayed more knowledge than both 2nd/3rd graders ($M = 8.03, SD = 2.01$) and K/1st graders ($M = 7.02, SD = 2.14$); however, the difference between 2nd/3rd graders and K/1st graders was only marginally significant ($p = 0.072$). No interaction effects were significant.

Differences in children's engineering domain knowledge (Research Question 2) were assessed with a 2 (gender) \times 2 (ethnicity) \times 3 (grade) \times 3 (domain: civil, mechanical, electrical/computer) mixed-design ANCOVA with school location as a covariate (see Table 1 for the corresponding percentages of students selecting the respective engineering items). Gender, ethnicity, and grade were included as between-subjects factors and domain was entered as a within-subjects factor. The main effect of domain was not significant ($p = 0.35$); however, the two-way interaction between domain and grade, $F(4, 612) = 2.77, p = 0.027$, and the three-way interaction between domain, ethnicity, and grade, $F(4, 612) = 5.02, p = 0.001$, were significant. Tests of simple effects revealed that for both the Caucasian and Latinx groups, domain differences were evident in K/1st grade and 4th/5th grade, but not in 2nd/3rd grade. Pairwise comparisons using a Bonferroni adjustment for multiple comparisons showed that Caucasian K/1st graders displayed more knowledge of civil ($M = 1.05, SD = 0.84$) and mechanical ($M = 0.97, SD = 0.82$) engineering

activities than electrical/computer engineering activities ($M = 0.61, SD = 0.79$). There were no significant differences between the civil and mechanical scores. In contrast, Latinx K/1st graders identified more electrical/computer activities ($M = 1.10, SD = 0.72$) compared to mechanical activities ($M = 0.72, SD = 0.81$). There were no significant differences between civil engineering ($M = 0.79, SD = 0.79$) and the other scores. For the upper grades, Caucasian students demonstrated a significant difference between electrical/computer ($M = 1.51, SD = 0.72$) and civil ($M = 1.08, SD = 0.80$) engineering activities and a marginally significant difference between electrical/computer and mechanical ($M = 1.24, SD = 0.77; p = 0.065$) engineering activities. Latinx 4th/5th graders showed a marginally significant difference between mechanical ($M = 1.09, SD = 0.73$) and civil ($M = 0.76, SD = 0.80; p = 0.06$) engineering activities, but no significant differences involving electrical/computer engineering activities ($M = 0.91, SD = 0.83$).

Perceived Knowledge of Engineering Occupational Activities

To examine grade level, gender, and ethnic differences in children's perceived knowledge of engineers (Research Question 3), a 2 (gender) \times 2 (ethnicity) \times 3 (grade) ANOVA was conducted. Results revealed a significant main effect for ethnicity, $F(1, 307) = 4.55, p = 0.034$, and a marginally significant main effect for grade, $F(2, 307) = 2.78, p = 0.061$. These results were qualified by a significant ethnicity by grade interaction, $F(2, 307) = 3.83, p = 0.023$. Tests of simple effects revealed that ethnic differences in perceived knowledge were only evident in 4th/5th grade students. In this age group, Caucasian students ($M = 1.16, SD = 0.61$) reported that they knew more about engineers when compared to the reports of Latinx students ($M = 0.80, SD = 0.71$). There were no significant gender effects.

Table 1.
Percentage of students who selected engineering items as a function of gender, ethnicity, and grade.

Engineering items	Ethnicity	K/1st		2nd/3rd		4th/5th	
		Girls (%)	Boys (%)	Girls (%)	Boys (%)	Girls (%)	Boys (%)
Make plans for roller coasters	Caucasian	52.9	38.1	50	40	62.2	70
	Latinx	20.7	44.8	20	36	58.3	43.3
Design heart monitors	Caucasian	23.5	33.3	35.7	52	70.3	79.2
	Latinx	48.3	62.1	30	24	29.2	50
Plan bridges and canals	Caucasian	64.7	52.4	39.3	36	62.2	66.7
	Latinx	24.1	48.3	20	40	41.7	43.3
Build robots	Caucasian	41.2	61.9	50	56	70.3	75
	Latinx	24.1	55.2	26.7	56	50	66.7
Write computer programs	Caucasian	41.2	23.8	39.3	36	78.4	75
	Latinx	58.6	51.7	26.7	40	45.8	53.3
Build tunnels	Caucasian	64.7	33.3	28.6	36	37.8	54.2
	Latinx	37.9	48.3	16.7	24	41.7	26.7

Association Between Overall Actual Knowledge and Perceived Knowledge

The association between children’s knowledge of occupational engineering activities and their perceived knowledge of engineers (Research Question 4) was examined by conducting a partial linear correlation controlling for both school location and grade level. Results indicated a significant positive partial correlation between overall knowledge and perceived knowledge, $r(315) = 0.15, p = 0.01$.

Interest in Engineering

Grade level, gender, and ethnic differences in engineering interest (Research Question 5) were examined with a 2 (gender) × 2 (ethnicity) × 3 (grade) ANCOVA with school location as a covariate. Main effects for ethnicity, $F(1, 306) = 4.13, p = 0.043$, and grade, $F(2, 306) = 4.29, p = 0.015$, were both significant; however, there was not a significant main effect for gender. Results for ethnic differences indicated that Caucasian students ($M = 1.62, SD = 0.48$) reported a stronger interest in engineering than Latinx students ($M = 1.35, SD = 0.67$). For grade, post hoc tests using a Bonferroni adjustment for multiple comparisons indicated that 4th/5th graders ($M = 1.58, SD = 0.52$) and 2nd/3rd graders ($M = 1.53, SD = 0.61$) both reported a stronger interest in engineering than K/1st graders ($M = 1.30, SD = 0.65$). There were no significant differences between 4th/5th graders and 2nd/3rd graders. No interaction effects were significant.

Association Between Actual Knowledge and Interest

The association between children’s actual knowledge of occupational engineering activities and their interest in engineering (Research Question 6) was examined by conducting a partial linear correlation controlling for both school

location and grade level. Results indicated a significant positive partial correlation between overall actual knowledge and interest, $r(315) = 0.15, p = 0.009$.

Common Misconceptions in Actual Knowledge

To explore common misperceptions in children’s actual knowledge of the occupational activities of engineers, we examined the percentage of students who selected each filler item by gender, ethnicity, and grade (see Table 2). Descriptive analyses suggest that children’s misperceptions differed by group. For instance, for early grades, the most common misperception of Caucasian girls and boys was “drive trains”; however, for Latinx children, the most common misperception for girls was “sell cars” and, for boys, the common misperceptions were “paint houses” and “help sick animals.” Within the middle age group, Caucasian girls selected “sell cars” most frequently, whereas Caucasian boys selected “drive trains.” For Latinx girls, “sell cars” and “help sick animals” were selected most frequently and, for Latinx boys, “sell cars” was the most frequent misconception. For the upper age group, the most frequent misconception for Caucasian and Latinx girls was “sell cars” and, for Caucasian and Latinx boys, it was “drive trains.” In general, the items that were selected the least were “sew clothes,” “help sick animals,” and “put people in jail.”

Discussion

Actual Knowledge of Engineering Occupational Activities

This study sought to examine the pre-existing knowledge of elementary school students about engineering occupations. Thus, the students were not exposed to any specific engineering outreach activity, nor any curriculum unit or informational presentation about engineering prior to completing the survey. Therefore, the observed survey results

Table 2. Percentage of students who selected filler items as a function of gender, ethnicity, and grade.

Filler items	Ethnicity	K/1st		2nd/3rd		4th/5th	
		Girls (%)	Boys (%)	Girls (%)	Boys (%)	Girls (%)	Boys (%)
Paint houses	Caucasian	35.3	19	7.1	20	5.4	0
	Latinx	51.7	55.2	16.7	28	12.5	13.3
Sell cars	Caucasian	29.4	9.5	46.4	24	16.2	8.3
	Latinx	58.6	41.4	26.7	40	20.8	16.7
Sew clothes	Caucasian	23.5	23.8	3.6	4	0	0
	Latinx	48.3	51.7	3.3	12	4.2	3.3
Drive trains	Caucasian	47.1	42.9	28.6	36	5.4	12.5
	Latinx	31	41.4	20	8	12.5	20
Help sick animals	Caucasian	23.5	14.3	10.7	8	0	0
	Latinx	51.7	55.2	26.7	28	0	6.7
Put people in jail	Caucasian	5.9	9.5	3.6	0	0	0
	Latinx	17.2	48.3	3.3	12	0	3.3
Trim bushes and grass	Caucasian	23.5	19	0	4	0	4.2
	Latinx	51.7	48.3	3.3	16	4.2	6.7

reflect the typical pre-existing knowledge about engineering in the examined student population.

As expected, older students demonstrated more knowledge of the engineering fields than younger children. This suggests that students develop some sense of the engineering fields during their elementary school years. Although older students appear to have some rudimentary knowledge of the engineering fields, some of their conceptions appear naïve. For instance, between 8.3 and 20.8% and between 5.4 and 20% of older students thought that engineers sell cars or drive trains, respectively (see Table 2). One possible explanation for these misconceptions is that students may focus on the noun in the phrase instead of the verb (Lachapelle et al., 2012; Lachapelle, Cunningham, & Lingren-Streicher, 2015). Overall, this suggests that it is very important to expose students early to the actual engineering fields before any misconceptions about what engineers do affect their attitudes and interest toward the engineering profession.

This current study is the first to examine ethnic differences in relation to students' developing knowledge of engineering. We found that Caucasian students demonstrated significantly more accurate knowledge of engineers compared to their Latinx counterparts. This seems partly due to the fact that Latinx students were more likely to circle the filler items in the KOAM-E questionnaire suggesting they had more misconceptions about what engineers do. Several factors could have contributed to these outcomes, such as stereotypes (Karatas, Micklos, & Bodner 2011; Knight & Cunningham, 2004), family science orientation (Gilmartin, Li, & Aschbacher, 2006), family socialization (Chesler & Chesler, 2002), and access to social capital (Martin et al., 2013). In this context, it is important to recognize that Latinx youth have unique cultural knowledge and aspirational social capital (Yosso, 2005). Future research should examine how engineering curricula and outreach activities can be designed in a culturally responsive manner (Alemán, Delgado Bernal, & Cortez, 2015; Elenes & Delgado Bernal, 2010) in order to effectively leverage the unique cultural knowledge and aspirational capital of Latinx youth (Davis-Kean et al., 2012; Villalpando & Solórzano, 2005).

Moreover, borrowing from gender schema theory (Martin & Harverson 1981; Martin, Ruble, & Szkrybalo, 2002), which posits that children are motivated to seek out same-gender information relative to other gender information, it is possible that Latinx students may demonstrate lower knowledge because they do not see learning about engineers as self-relevant, given the prototypical stereotype of an engineer being a White male.

Unlike ethnic differences, the differences in gender were at trend level. It is possible that gender differences become more solidified as children become older and learn more about engineering. This might suggest that further involvement and experiences with engineering in early grades when gender differences were not apparent may help to

keep students' knowledge about the engineering field equivalent between males and females.

Perceived Knowledge of Engineering Occupational Activities

When interpreting the results for perceived knowledge of engineers, it is again important to note that the purpose of this study was to examine the pre-existing perceptions. That is, the students were not provided with any specific engineering curriculum unit or engineering outreach activity. Rather, the survey results reflect the pre-existing perceptions of the examined student population. Similar to the findings for children's actual knowledge of engineering, we found that Caucasian students reported that they knew more about engineering than Latinx students. However, this difference in perceived knowledge of engineering was only apparent in the older age group of 4th/5th grade students. Thus, for this older age group, the pattern in perceived knowledge matched the pattern in actual knowledge. This close correspondence between perceived and actual knowledge for the older age group could be due to the fact that the older students may generally be giving more accurate representations of what they know, due to their more sophisticated metacognitive skills (Paris & Newman, 1990). Interestingly, in the young (K/1st grader) age group and the middle (2nd/3rd grader) age group, both Caucasian students and Latinx students had equivalent levels of perceived knowledge of engineering occupational activities. It will be interesting to examine in future work how these equivalent perceived knowledge levels relate to perceived self-efficacy in the occupational activities; potentially, these equivalent perceived knowledge levels could be leveraged when developing culturally responsive engineering outreach activities (Eglash, Gilbert, & Foster, 2013; Villalpando & Solórzano, 2005).

We did not find any gender differences in perceived knowledge of students. This likely reflects that elementary school girls and boys have a similarly naïve understanding of engineering. These results parallel the lack of gender differences in the actual knowledge of children. In fact, in general we did find a positive correlation in children's actual and perceived knowledge of engineering, suggesting that children have some recognition of what they know, and what they do not know, about engineers.

Another unique contribution of the current study is that we explored children's domain-specific engineering knowledge. In general, we found that the children's domain knowledge varied according to grade level and ethnicity. For example, K/1 Caucasian students know more about civil and mechanical engineering, whereas Latinx children at that age know more about electrical/computer engineering. Yet, this trend changes by the 4th/5th grade in that Caucasian children demonstrated more knowledge about electrical/computer engineering versus Latinx children who demonstrated more

knowledge about mechanical engineering. This illustrates that children's representation of a prototypical engineer may change with age, and may depend on a child's ethnic background. Therefore, it is important to provide young children with broad and accurate knowledge of occupational activities of engineers, which is consistent with recent results of survey studies of parents of Latinx students (Hernandez, Rana, Alemdar, Rao, & Usselman, 2016). This knowledge could be incorporated into rigorous curricula that prepare K-12 students for challenging college programs; such preparation has been found conducive for the educational journeys of Latinx students toward engineering careers (Brown, 2002).

Interest in Engineering

The patterns for students' pre-existing interest parallel what we found for students' pre-existing knowledge about engineering. Caucasian students show significantly more interest in engineering than Latinx students regardless of gender. Recent statistics indicate that minorities earn relatively fewer engineering degrees than Whites (Colby & Ortman, 2015; NSF, 2015), and the findings from this study show that disparities in interest begin as early as elementary school. This underscores the necessity of culturally responsive outreach interventions beginning in elementary school. It is promising to see that older elementary school students reported stronger interest in engineering than younger students; this is likely due to their increased knowledge of what engineers do. In fact, we found a positive association between students' knowledge of and interest in engineering. This highlights that outreach interventions that teach children broad and accurate representations of what engineers do may also influence their interest in pursuing engineering.

Unlike studies of older students in grades 8–12 (Chan et al., 2000; Ing et al., 2014) and college freshmen (Besterfield-Sacre et al., 2001), which found significant differences between the engineering-related attitudes of males and females, the present study of elementary school students did not find significant gender differences. In particular, this study found an only marginally significant higher knowledge of engineering occupational activities by boys ($M = 8.50$, $SD = 2.41$) compared to girls ($M = 8.35$, $SD = 2.41$), and no differences between the interest levels of boys and girls for engineering. This result is consistent with the equivalent enjoyment levels of female and male elementary school students in a recent study on electrical engineering activities, which contrasted with significantly higher enjoyment levels for male high school students compared to female high school students (Reisslein et al., 2013). Our results contribute to the emerging understanding that the attitudes of female and male students related to engineering diverge during the middle school years (grades 6–8). A continuous intervention program that begins in elementary school grades and accompanies

students throughout elementary and middle school years may help in preserving the equivalent interest levels of both genders toward engineering as they grow older. Examining the effect of such continuous intervention programs is an important direction for future research.

A limitation of the examination of interest in engineering in this study is that the elementary school students were not provided with an introductory curriculum unit or outreach activities about engineering prior to completing the survey measure. This study design was adopted in order to obtain the pre-existing actual and perceived knowledge of engineering in the examined elementary student population. This study may therefore examine the interest that corresponds to naïve, or potentially incorrect, knowledge of engineering occupational activities. Future research needs to specifically examine the interest of students in occupational activities that engineers typically engage in and compare with the interest results obtained in the present study. We also note as a limitation that we did not assess children's actual prior experiences with engineering through parent or child reports to possibly examine whether Caucasian children had more engineering exposure than Latinx children.

Conclusion

This study aimed to fill gaps in the literature regarding knowledge and interest toward engineering in early elementary school. Findings revealed that Caucasian and older children displayed greater knowledge of and interest in engineering compared to Latinx and younger children. Findings also revealed that both genders had equivalent knowledge and interest levels. These results highlight that ethnic disparities in knowledge and attitudes toward engineering occupation may begin as early as elementary school. Thus, culturally responsive interventions to promote children's interest in engineering should be introduced in kindergarten and should include components to increase children's knowledge of the diverse roles performed by engineers.

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