Expanding access to engineering for underrepresented groups has by and large focused on ethnicity/race and gender, with little understanding of socioeconomic disadvantages. In this study, we use economic, human, and cultural capital theories to frame and then describe access to undergraduate engineering degree programs and bachelor’s degrees. Using individual student-level data from 10 universities from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) and aggregate school-level data (i.e., free-lunch status) from the Common Core of Data between 1994 and 2003, we first describe students who enter engineering programs by peer economic status (PES) with attention to gender, ethnicity/race, and SAT Math score. Second, a subset of the data is analyzed to describe access to bachelor’s degrees in engineering by PES using graduation rates. The findings show an increase in access to engineering degree programs by disadvantaged students, but that access to engineering bachelor’s degrees may be constrained, and especially for underrepresented ethnic/racial groups. The data highlight variable PES differences that accrue in engineering at entry and upon graduation (6 years later) across ethnic/racial groups; these differences have implications for broadening participation. Recommendations for future research and improving engineering access at the secondary and postsecondary levels are discussed.

Over the past 80 years, various stakeholders have promoted engineering as a field where the U.S. lacks sufficient academic and workforce participation (National Science Board, 2003). Among concerns is the
need to increase participation by historically underrepresented students, namely women, African American (also referred to as Black), Hispanic (subsequently referred to as Latina/o), and Native American students (National Science Foundation [NSF], 2012). In 1990, historically underrepresented ethnic/racial groups constituted nearly 25% of the American population (U.S. Census Bureau, 2012), just more than 15% of the four-year college-going population, but only 7.6% of engineering bachelor’s degrees conferred (U.S. Department of Education, 2012). Despite the plethora of outreach and retention programs encouraging underrepresented student participation, undergraduate engineering enrollment and completion by women and minorities has improved only modestly (NSF, 2012). As of 2003, historically underrepresented ethnic/racial minorities constituted around 21% of four-year undergraduates, but only 15% of the four-year undergraduate engineering enrollment (NSF, 2012, Table 2–4 & 2–9). Similarly, women comprised more than half of all undergraduates, but earned only 20% of the degrees in engineering (Gibbons, 2011).

Some researchers have questioned the almost exclusive focus on gender and ethnicity/race as primary mechanisms influencing undergraduate engineering participation, experiences, and outcomes (e.g., Ohland, Orr, Lundy-Wagner, Veenstra & Long, 2012; Sheppard et al., 2010). In fact, with soaring college tuition, the increasingly limited availability of scholarships and grants, and the economic recession of 2008, there has been considerable attention to socioeconomic background, and specifically low-income students (e.g., Engberg & Allen, 2011; Terenzini, Cabrera, & Bernal, 2001). That body of research consistently shows that low-income students are disadvantaged with regard to high school completion, college matriculation, and postsecondary outcomes (e.g., Advisory Committee on Student Financial Assistance, 2010; Kezar, 2010).

However, those contributions are limited in two ways. First, those analyses typically fail to shed light on specific academic fields, such as engineering. Since bachelor’s degrees in engineering often require no further higher education (or are effectively the first professional degree) and promise high earnings (Carnevale, Smith, & Melton, 2011; Engineering Workforce Commission, 2009), participation and success fulfill the promise of economic stability and social mobility for low-income and other marginalized families. Second, the practical focus on low-income status implicitly privileges economic issues, and overlooks more socioeconomic elements of disadvantage (Bourdieu & Passeron, 1977; Lareau & Conley, 2008). (For clarity, in this research low-income status is just one potential component of socioeconomic disadvantage.) By understanding the socioeconomic background of students who enter four-
year engineering bachelor’s degree programs, stakeholders will have better information relevant for increasing participation in engineering.

**Purpose**

Postsecondary institutions are increasingly diverse, not only in terms of gender and ethnicity/race, but also by socioeconomic status (Baum & Ma, 2007; Engle & Tinto, 2008; Terenzini et al., 2001). Socioeconomic disadvantage is operationalized in higher education research in a variety of ways, including first-generation status, parent education level, parent occupation, parent income level, an index of the latter three, or Federal Pell grant eligibility. Regardless of measurement, privacy laws and considerations largely prevent the release of individual financial information, making complementary or proxy measures for socioeconomic status necessary for research.

To remedy this, some researchers have focused explicitly on the relationship between peers’ economic background and academic outcomes in engineering (e.g., Orr, Ramirez, & Ohland, 2011). That research builds off of the K–12 research on low-income students (e.g., Aud et al., 2011; Caldas & Bankston, 1997) by connecting the average percent of free lunch eligible students in a postsecondary student’s high school to their individual-level college data using a variable, Peer Economic Status (PES). Although the PES is not an individual-level measure of low-income status, it describes the prevalence of poverty, or the low-income population, at a students’ high school. Since school-level poverty is correlated with individual-level poverty, academic achievement (especially in mathematics), postsecondary matriculation, and school resources (e.g., Advisory Committee on Student Financial Assistance, 2010; Aud et al., 2011; Lee & Wong, 2004; Owens, 2010), PES is an alternative measure for understanding access to, participation in, and completion of four-year undergraduate engineering programs that goes beyond ethnicity/race and gender and may have important implications for engineering (e.g., Hill, Corbett, & St. Rose, 2010).

Similar to the K–12 research, postsecondary students’ individual socioeconomic backgrounds and institution-level characteristics both appear to play an important role in postsecondary matriculation. Not only do less-privileged students matriculate to four-year institutions at lower rates, but they also tend to enroll in less selective institutions that often enroll more low-income and disadvantaged students (e.g., Horn, 2006). Further marginalizing these students is the fact that the institutions they enroll in tend to have organizational-level economic capital deficits (e.g., tuition revenue as a percent of total revenue and general
expenditures per full-time equivalent student) that are negatively related to persistence and completion (Horn, 2006; Ryan, 2004).

The purpose of this research is to more fully characterize socioeconomically disadvantaged student access to undergraduate engineering programs and degrees. This research answers the following primary research questions: (1) Did matriculation of students from diverse socioeconomic backgrounds (as defined by PES) expand between 1994 and 2003? (2) How did the socioeconomic profile of students matriculating into four-year engineering programs between 1994 and 2003 vary by gender and ethnicity/race? and (3) What is the socioeconomic profile of students who matriculated into engineering and completed a bachelor’s degree within six years?

This research builds upon the extant literature in terms of content and methodological approach. First, we simultaneously contextualize the higher education research on socioeconomically disadvantaged students by focusing on engineering and extend the engineering education research by focusing on socioeconomically disadvantaged students. Second, in the spirit of a recent body of work (i.e., Chen and Ohland, 2012; Ohland et al., 2012; Orr et al., 2011), we use the PES variable to connect an aggregate measure of high school poverty to individual-level postsecondary data with a stronger theoretical underpinning.

Theoretical Frameworks and Literature Review

To date, there is relatively little research on socioeconomically disadvantaged engineering undergraduates; thus, to answer the primary research questions we examined three bodies of work. First we reviewed literature on socioeconomically disadvantaged and low-income students, high school poverty, and academic achievement as a foundation for understanding the importance of precollege individual- and school-level poverty on postsecondary matriculation. Second, we reviewed the higher education literature on socioeconomically disadvantaged students and college access. Finally, we reviewed the engineering education research to shed light on socioeconomically disadvantaged students within the four-year undergraduate engineering context. Before characterizing these bodies of literature, we describe the economic, human, and cultural capital theories that frame this work.

Economic, Human, and Cultural Capital Theories

As Massey, Charles, Lundy, and Fischer (2003) note, economic capital refers to an individual’s economic resources, which may include family income, savings, or other assets. In this view, there is a positive
and direct relationship between economic capital and privilege. That is, high school students from more economically privileged backgrounds have financial resources that afford them opportunities like living in middle-class neighborhoods, attending good schools, having access to private tutoring, employing college coaches, and understanding the machinations of financial aid (e.g., Engberg & Allen, 2011). Conversely, students who lack economic capital tend not to have access to these costly resources. To acknowledge and remedy these disparities (e.g., attending less well-resourced schools and having less discretionary income), outreach like the federal TRIO program, which includes the Gaining Early Awareness and Readiness through Undergraduate Preparation (GEAR-UP) program, were established to acknowledge and address socioeconomic disadvantages and promote college access and success (Saifer & McDermott, 2011).

Although money is important, human capital theory (Becker, 1962) provides additional perspective to understand college matriculation. This theory suggests that individuals make decisions based on rational choice, evaluating the direct and indirect costs associated with their decisions (Becker, 1962). In the context of higher education, students specifically weigh the costs of attending college versus entering the workforce in their decisions on whether or not to apply, enroll, and matriculate to a two- or four-year institution (e.g., Perna, 2000). Human capital theory incorporates the importance of money (economic capital), but also acknowledges the knowledge, skills, and abilities students have access to (typically via parents) that inform their decision making. However, student conceptions of the costs and benefits of attending college are not uniform across groups (e.g., Beattie, 2002; Perna, 2000). In fact, Beattie’s (2002) analysis of the High School and Beyond data indicate that economic theories best explain postsecondary enrollment for White, male students from low-to-average socioeconomic origins and low-to-average cognitive skills, providing less insight on the behaviors of students with relatively higher and lower cognitive skills, as well as female, ethnic/racial minority, and relatively higher-income peers. While this work is important, it omits specific academic contexts, like engineering.

Given the inability of human and economic capital to explain across-group behavior, some scholars include notions of cultural capital to further explain economically based theories of college matriculation (e.g., Perna, 2000; Owens, 2010; Roksa & Potter, 2011). Pierre Bourdieu’s (1984) theory of culture and stratification extends the economic and human capital frameworks by positing that students enter schools with varying levels of relevant cultural capital (i.e., knowledge, skills,
and tastes), dispositions, and attitudes (termed habitus). Cultural capital theory concedes that the student-institution interaction plays a critical role in students’ college-going and related decisions, and that only the cultural capital that is valued by an institution will be rewarded. In their conception (Bourdieu & Passeron, 1977), all students have cultural capital, but those from higher social classes (e.g., parents with better occupations, more education, and higher incomes) would have more relevant cultural capital, and use it more effectively to successfully navigate schools. By extension, students attending high-poverty schools are more likely to have fewer economic resources (economic capital), have parents who have not completed a four-year degree and/or have little college knowledge (human capital), and lack dispositions or preferences that would orient them toward four-year undergraduate engineering programs (cultural capital).

Although economic, human, and cultural capital theories are distinct, taken together they provide a broad and complicated understanding of how a student’s socioeconomic background (e.g., family income, parent’s education, and high school poverty level) can inform decisions, attitudes, and preferences about college matriculation, major selection, and degree completion. Since engineering promises higher anticipated wages and job stability, economic and human capital theory suggest that undergraduate engineering programs would be desirable for socioeconomically disadvantaged students. However, concomitant with cultural capital theory, socioeconomically disadvantaged, low-income and students in high-poverty high schools are likely to have college-related cultural capital that is less recognized and/or valued (e.g., Bourdieu & Passeron, 1977; McDonough & Calderone, 2006). In addition, application of the capital theories presumes that these students are less likely to have high academic trajectories, above average academic achievement, and the cultural capital or habitus (from family) that would contribute to their choice of a four-year undergraduate engineering program (Owens, 2010; Roska & Potter, 2011).

**Socioeconomic Disadvantage, High School Poverty, and Academic Outcomes**

The K–12 research literature consistently shows that both individual- and school-level measures of poverty significantly affect student academic outcomes (Advisory Committee on Student Financial Assistance, 2010; Aud et al., 2011; Owens, 2010; Rumberger & Palardy, 2005). Scholars tend to include parent education and occupation, as well as family income (as measured by free or reduced lunch [FRL] status) in research on individual-level poverty. FRL eligibility is a considered a
relatively objective variable based on family incomes less than 130% or 180% (respectively) of the poverty line that also accounts for household size (Aud et al., 2011). By and large, the research on individual-level poverty shows that students who are eligible for FRL consistently perform less well, have lower academic aspirations, and are less likely to progress in math and science courses than students who come from families with higher incomes, regardless of ethnicity/race or gender (Advisory Committee on Student Financial Assistance, 2010; Aud et al., 2011).

While FRL status sheds important light on individual-level poverty, researchers have argued that school-level poverty also plays a role in reinforcing stratification and inequality, incorporating frameworks that account for economic, human, and/or cultural capital theories. In that body of knowledge, a family’s economic capital is related to the type of neighborhood they live in, school peer sociodemographic composition, school resources, as well as attitudes about schools and college-going (Beattie, 2002; Caldas & Bankston, 1997; Lee & Wong, 2004; Rumberger & Palardy, 2005). This suggests that both individual- and institution-level measures of poverty influence student outcomes. Rumberger and Palardy (2005) take that one step further in their work where school socioeconomic status had a stronger effect on student outcomes than the individual-level measures of socioeconomic status, a finding alluded to by others (e.g., Caldas & Bankston, 1997; Owens, 2010). Taken together, this research suggests that the school context, and specifically high school poverty, is at least as important as, and possibly more important than, students’ individual sociodemographic characteristics on academic outcomes.

Disadvantaged Students and College Access

The relationship between socioeconomic disadvantage and college matriculation persists from secondary to tertiary education. That is, privileged students have advantages that contribute to their increased likelihood for matriculating to four-year institutions, including attending better high schools as well as being exposed to more college preparatory courses and the associated culture. In comparison, their less privileged peers who attend poorly resourced high schools, may not have a parent who attended college, and/or come from low-income backgrounds are more likely to enroll in two-year institutions, if they choose college at all (Baum & Ma, 2007; Engle & Tinto, 2008; Terenzini et al., 2001). Although FRL data rely solely on family income data, even among those low-income students deemed academically qualified for college (i.e., having taken Algebra II), the Advisory Committee on
Student Financial Assistance (2010) found persistent disparities in college matriculation between low- and moderate-income students. Further, the data suggest that lower-income students have become more disadvantaged in terms of college access over time. Given that persistence and timely graduation with an engineering bachelor’s degree requires high levels of mathematics upon matriculation, the data indicate that students from socioeconomically disadvantaged schools will be less likely to pursue engineering. While the literature emphasizes the negative relationship between socioeconomic disadvantage and college matriculation, complementary research suggests that the strength of the relationship is not fully explained by academic achievement (Baum & Ma, 2007), or the availability of financial aid (Dee & Jackson, 1999; Perna et al., 2009).

Despite the contributions of higher education research toward understanding socioeconomically disadvantaged students’ transition from high school to college, this research provides little insight to specific fields, like engineering. This gap is problematic given that students who matriculate into engineering degree programs tend to have higher levels of pre-college preparation and achievement, especially in math and science (Dee & Jackson, 1999; Veenstra, Dey, & Herrin, 2009). Further, the curricular momentum associated with that preparation is related to progression and success in postsecondary engineering (Astin & Astin, 1992; Xie & Shauman, 2005).

**Disadvantaged Students in Engineering**

In 2010, first-year undergraduate enrollment in engineering reached 118,831, representing a 23% increase from 2001 (Gibbons, 2011). Despite that enrollment trend, the proportion of freshmen who indicate engineering as a preferred major has been rather stagnant at 9–10% since the mid-1990s (National Science Board, 2012, Appendix Table 2–12; Pryor, Hurtado, DeAngelo, Palucki Blake & Tran, 2010). While the steady interest in engineering could be considered positive, the lack of insight as to how knowledge and preferences reflect student’s socioeconomic status is unfortunate given various efforts related to expanding college access (Kezar, 2010; Saifer & McDermott, 2011).

Research on expanding access to engineering has focused largely on gender and ethnicity/race (e.g., Chubin, May, & Babco, 2005; Fox, Sonnert & Nikiforova, 2009; Hill et al., 2010; NSF, 2012; Ohland et al., 2011; Perna et al., 2009). Despite the large gender gaps in engineering matriculation, most of this work found few significant differences in terms of persistence and degree completion (Hill et al., 2010; Ohland et al., 2011). However, the study by Ohland et al. (2011) of success in
engineering using Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) concluded that “trajectories of persistence are non-linear, gendered, and racialized” (Ohland et al., 2011, p. 244). In effect, they suggest that data that relies heavily on White male students must be disaggregated by ethnicity/race and gender in order to properly identify subgroup performance and/or experiences. However, the authors allude to the importance of institutional, state, and regional contexts which may vary in terms of standards for high school completion and college readiness, college-going rates, and presence of an engineering-based workforce—all traits that can be associated with measures of social class or socioeconomic status.

The NSF (2012) acknowledges that the lack of data on family income and socioeconomic status in engineering participation is problematic. In fact, research on flexibility and inclusivity by engineering education scholars suggests that social class should be explored further. For example, in her work understanding the gendered nature of engineering, Pawley (2004) suggests that women have been “designed out” of the field through sorting and organization of different tasks. A similar argument could be made for socioeconomically disadvantaged students given the aforementioned structural disparities in K–12 education systems that effectively exclude students who attend high poverty high schools, and have poor academic preparation, little understanding of college readiness or knowledge about engineering.

Others discuss how the professionalization of engineering has been problematic for broad notions of diversity that include class. For example, Lucena (2003) alludes to the way social class has been neglected in engineering through structural and curricular issues. Among other things, he notes how the lack of multiple entry points, the inability to accommodate individual learning speeds, and the omission of social, political, and/or economic identity in engineering classrooms can contribute to a lack of socioeconomic (and/or other) diversity in engineering. These contributions highlight the philosophical progress engineering educators have made to discern and examine structural barriers (see also Fox et al., 2009).

Helping to contextualize social class disparities in engineering, various scholars have begun to examine the role of family background, low-income, and/or socioeconomic status (Freeman, Persaud, Kharem, Rothwell, & Yoder, 2010; Ohland et al., 2012; Orr et al., 2011; Sheppard et al., 2010). Like research on secondary schools, most of this work shows a negative relationship between socioeconomic disadvantage and educational outcomes. In fact, the construction of PES has facilitated a substantive body of research using a conceptually based proxy for
socioeconomic status to explore postsecondary outcomes in engineering. For example, in their earlier analysis of MIDFIELD, researchers concluded that students entering engineering were more likely to have attended high schools with lower levels of high school poverty (Ohland et al., 2012; Orr et al., 2011). While a student may not come from a low-income background, attending a high-poverty high school is associated with fewer school resources, lower academic aspirations, and higher rates of attrition.

In addition, school peers’ expectations have a strong influence on education planning and persistence overall, and in engineering or related fields (Astin & Astin, 1992; Beattie, 2002; Owens, 2010). Ohland et al. (2012) found differences in student experiences and graduation rates by socioeconomic status and ethnicity/race, but not uniformly across or within groups. Another notable variability in socioeconomic status was identified by Sheppard et al. (2010), who found that most undergraduate engineering students had financial concerns, but that ethnicity/race, socioeconomic status, and gender provided additional dimensions of understanding. In particular, they found disadvantaged engineering undergraduates felt greater financial pressure during college and had lower confidence with regard to their engineering-related skills when compared to their more financially privileged peers (Sheppard et al., 2010).

While engineering enrollments are among the highest that they have ever been, the extant research fails to provide a baseline understanding of engineering access and success beyond ethnicity/race and gender. Although engineering education literature is buttressed by the work in K–12 and higher education, it lacks theory to explain how socioeconomic status works to influence access and completion. In fact, the theoretically based conjectures may be difficult to identify given that on the one hand, economic and cultural capital theories suggest that disadvantaged students might be more likely to choose engineering because of higher future wages and socioeconomic mobility. Yet, on the other hand, human and cultural capital theories suggest that disadvantaged students may not choose engineering because of less rigorous secondary achievement, as well as a lack of relevant cultural capital from their parents (who on average, have relatively less knowledge about college and engineering). In addition, while the focus on low-income students implies an economic capital framework, the practical, albeit arbitrary, cut off of 130% of the poverty line lacks a theoretical basis for extrapolation.

While stratification theories suggest that student interest and success in engineering is derived from their economic background (i.e., parents
Disadvantaged Engineering Undergraduates

income level and type of high school attended) and academic achievement (e.g., completing advanced mathematics), research suggests that sociocultural issues also matter (i.e., gender, ethnicity/race, and cultural capital). To better characterize access to engineering programs and bachelor’s degrees for socioeconomically disadvantaged students we use human, economic and cultural capital theories to build upon the work of Ohland and colleagues (2011, 2012) with MIDFIELD and the PES variable.

Methods

Data Sources

The data reported in this paper is from two sources: MIDFIELD and the U.S. Department of Education (2010) Common Core of Data (CCD). MIDFIELD includes student record data from 11 public institutions, including five of the ten largest U.S. undergraduate engineering programs, four of the top ten producers of Black engineers, and two historically Black colleges or universities (Long, 2013). Data for MIDFIELD students include gender, ethnicity/race, zip code at matriculation, year in school, enrollment status, academic major, and transcripts. By design, engineering students are overrepresented in MIDFIELD, a feature that enables the analyses of subpopulations (i.e., by socioeconomic status, gender, and ethnicity/race). Although MIDFIELD includes 11 institutions with data from 1988 to 2009, this study uses the 1994–2003 cohorts for which all institutions reported high school data; one institution did not report high school data at all and therefore was excluded. The remaining ten institutions enrolled 549,621 students during between 1994 and 2003, of which 419,581 were full-time students. After removing international, transfer, and those students who did not report a specific ethnicity/race, 364,816 students remained.

MIDFIELD does not contain information on individual students’ socioeconomic background, so we used high school poverty as a measure of socioeconomic status, a variable derived from data in the CCD (e.g., Aud et al., 2010; Caldas & Bankston, 1997; Ohland et al., 2012; Orr et al. 2011). The CCD is sponsored by the National Center for Education Statistics and makes available data collected from U.S. high schools, including enrollment counts and the number of students eligible for free or reduced lunch in a given school year. Of the 11,721 high schools represented in MIDFIELD for full-time students, 7,517 (or 65%) could be matched with public schools in the CCD with non-missing values for the required data for at least one year between 1990 (the first year the
1994 cohort was in high school) to 2002 (the last year that the 2003 cohort was in high school). It is important to clarify that reduced lunch eligibility was first recorded by NCES during the 1998–1999 school year (U.S. Department of Education, 2010); however, since this analysis includes data that precedes that designation, we only use free lunch eligibility.

The linked MIDFIELD and CCD data allow computation of the Peer Economic Status (PES) variable which captures the average percentage of students attending high school with each MIDFIELD student that was not eligible for free lunch during the four years a student was expected to be in high school. If no CCD data were available for the four years a student is expected to have been in high school, the average PES for that school between the 1990 and 2002 academic years was imputed. We were able to match 80% of the MIDFIELD students with a high school in the CCD with percent of students with free lunch eligibility, leaving data from 241,787 full-time students for analysis (data for 11,721 students were imputed). High values of PES represent high schools with higher economic status or those where the free lunch eligible population, a poverty proxy, is low. It is important to note that PES is not necessarily an indication of an individual student’s household income or economic status, but rather an indicator of high school poverty and the socioeconomic status of MIDFIELD students’ high school peers.

**Analytic Strategy**

To answer the primary research questions, we conducted descriptive analyses primarily to characterize our population data. Since the data was very non-normal, most analyses involved using the median PES. We also used inferential analyses where appropriate; specifically, we conducted regression trend analyses on the median PES over time for each university to understand differences in the socioeconomic profile over time of students. We used SAS and Minitab software for the analysis. We defined full-time student status as enrollment in an average of at least 12 hours each semester (or at least 8 per quarter). Thus the final MIDFIELD research database used for this study included data from first-year matriculants in all non-engineering majors (N = 192,020) and in engineering (N = 49,767) from 1994–2003.

We used descriptive statistics to identify how access to MIDFIELD institutions and specifically to engineering programs at MIDFIELD institutions, changed between 1994 and 2003 for socioeconomically disadvantaged students. Given the importance of both within- and across-
institution variability, we also examined trends in PES by MIDFIELD institution for context and demographic group. The population studied is 76% White, 14% African American, 6% Asian, 4% Latina/o, and less than 1% Native American. Typical of engineering enrollments, 78% of the sample is male. Since some research suggests that ethnic/racial gaps are moderated by academic achievement, we also examined the relationship between median SAT Math score and PES.

Using a broad notion of access, we complement the aforementioned work with analysis of bachelor’s degree completion for students starting in engineering. We used cohorts entering MIDFIELD institutions between 1994 and 1997 ($N = 90,896$ full-time students) and reviewed the distribution of PES for full-time students who initially chose engineering and graduated (in any major) within six years ($N = 19,697$). These cohorts were included because they were the most complete and representative of the 10 MIDFIELD institutions with sufficient high school data. We omitted students who switched into engineering from other majors because that population is relatively small (Ohland, Sheppard, Lichtenstein, Eris, Chachra, & Layton, 2008). A summary of the data used in these analyses is presented on Table 1.

<table>
<thead>
<tr>
<th>Summary of MIDFIELD and CCD Data for Analysis</th>
<th>Number of Full-Time Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIDFIELD Population</strong></td>
<td></td>
</tr>
<tr>
<td>Total matriculated students 1994–2003</td>
<td>419,581</td>
</tr>
<tr>
<td>Domestic only</td>
<td>399,908</td>
</tr>
<tr>
<td>First-time at this college/university</td>
<td>308,159</td>
</tr>
<tr>
<td>Race/ethnicity identified</td>
<td>301,737</td>
</tr>
<tr>
<td>PES calculated</td>
<td>241,787 (80%)</td>
</tr>
<tr>
<td>Engineering matriculants</td>
<td>49,767</td>
</tr>
<tr>
<td>Non-Engineering matriculants</td>
<td>92,020</td>
</tr>
<tr>
<td>High School Represented</td>
<td>11,721</td>
</tr>
<tr>
<td>Schools with PES calculated</td>
<td>7,571 (65%)</td>
</tr>
<tr>
<td><strong>Graduation Rate Cohorts</strong></td>
<td></td>
</tr>
<tr>
<td>Total matriculated 1994–1997</td>
<td>90,896</td>
</tr>
<tr>
<td>Matriculated in engineering</td>
<td>19,697</td>
</tr>
<tr>
<td>Graduated in six years in engineering</td>
<td>10,419 (53%)</td>
</tr>
</tbody>
</table>
Limitations

This study contains at least four important limitations. First, the use of FRL status as a proxy for socioeconomic disadvantage can be flawed by misclassifications of eligibility, a lack of sensitivity, and unaccounted-for effects from a decline in participation among older adolescents (Entwisle & Astone, 1994). However, Ensminger et al. (2000) suggests that it is consistent with other socioeconomic variables, particularly income level. Second, given that we only use free lunch eligibility in the analysis our estimates are likely more conservative than if we included students who qualify for both free and reduced lunch. Third, students attending private high schools were not included in this analysis. However, private high schools are not required to report FRL status and only represent approximately 8% of high school students (National Center for Education Statistics, 2012, Table 3). However, students attending private schools may account for a disproportionate amount of the missing data on MIDFIELD students’ high schools (20%). Fourth, this research is primarily descriptive because MIDFIELD includes entire population data; thus, inferential statistics are employed minimally, as those methodologies are typically used to make observations about the population based on a sample. That said, our analyses may not be generalizable to national data or even data from institutions in other states/regions of the United States. Relatedly, we do not test the effect of any specific local or national class-based intervention, which could provide a more acute assessment of socioeconomically disadvantaged student access to undergraduate engineering programs and bachelor’s degrees.

Findings

Access to Engineering Degree Programs

To contextualize socioeconomically disadvantaged student access to undergraduate engineering degree programs at the ten MIDFIELD schools, we first conducted analyses on the entire population of first-time, full-time MIDFIELD students between 1994 and 2003. Figure 1 presents the distribution of PES for all first-time, full-time MIDFIELD students in engineering and non-engineering majors between 1994 and 2003. Both distributions are non-normal, and therefore we use the median as an indicator of centrality of the distribution rather than the average in all subsequent analyses.

Given the importance of institutional context, we also reviewed the median PES of all full-time students by institution, which ranged from
78.6 to 96.2 among the 10 MIDFIELD institutions. During the ten-year period under study, 8 of the 10 institutions exhibited a decrease in median PES between 1994 and 2003; two institutions had an increase. As a group, the median PES of the 10 MIDFIELD institutions decreased toward the end of the ten-year period. In testing for differences using a two-way analysis of variance (ANOVA), we found a significant difference in median institutional PES for first-time, full-time students at the MIDFIELD institutions ($p < 0.0001$), and by year between 1994 and 2003 ($p < 0.0001$).

The shapes of the PES distributions in Figure 1 are similar regardless of whether students initially declare engineering or another major. For first-year engineering students at MIDFIELD schools the median PES is 91.6, which is statistically greater than that of non-engineering students, 90.6 ($p < 0.0001$), but indicates a difference of only 1%. In addition, comparison of the cumulative distributions with the Kolmogorov-Smirnov (K-S) test (Owens, 1962) shows the maximum difference of 5.4% at PES = 95.0 and is statistically significant ($p < 0.0001$). This indicates that the largest difference in engineering matriculation arises among students who attended the most privileged high schools.
Table 2 summarizes the results of a regression for median institutional PES by year (1, 2, . . ., 10) for each MIDFIELD institution over the ten-year study period. The residuals of the median PES approximately followed a normal distribution, indicating that the assumptions of regression were followed. Four of the ten institutions had a significant decrease in the median PES, indicating a significant expansion of economic diversity among first-year engineering undergraduates. None of the institutions had a significant increase in median PES over time.

Gender and Ethnicity/Race. To answer the second research question we examined PES by ethnicity/race and gender. The median PES for female engineering students was 91.0% compared to 91.8% for male students, a difference of less than 1%. A two-way ranked scores ANOVA on PES by gender and ethnicity/race found no statistically significant difference in median PES by gender (F(1, 49,538) = 1.59, \( p = 0.207 \)), thus, subsequent analyses focused only on gender differences within ethnic/racial groups. The two-way ANOVA for ethnicity/race (minus Native American students due to small sample size) revealed a statistically significant difference in median PES (F(3, 49,538) = 864.9, \( p < 0.0001 \)).

Figure 2 highlights the difference in median PES by ethnic/racial group. Asian (92.2%) and White (92.3%) engineering students had higher median PES than their Latina/o (88.4%), Native American (85.3%), and Black (81.4%) peers. Compared to the differences in median PES by ethnicity/race on Figure 2, the within-group difference

<table>
<thead>
<tr>
<th>MIDFIELD Institution</th>
<th>Slope</th>
<th>Adjusted R² (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-0.409*</td>
<td>52.3</td>
</tr>
<tr>
<td>B</td>
<td>-0.276**</td>
<td>85.7</td>
</tr>
<tr>
<td>C</td>
<td>-0.295*</td>
<td>41.3</td>
</tr>
<tr>
<td>D</td>
<td>-0.345**</td>
<td>55.9</td>
</tr>
<tr>
<td>E</td>
<td>-0.437</td>
<td>32.2</td>
</tr>
<tr>
<td>F</td>
<td>-0.197</td>
<td>15.9</td>
</tr>
<tr>
<td>G</td>
<td>-0.040</td>
<td>0.0</td>
</tr>
<tr>
<td>H</td>
<td>-0.021</td>
<td>0.0</td>
</tr>
<tr>
<td>I</td>
<td>+0.021</td>
<td>0.0</td>
</tr>
<tr>
<td>J</td>
<td>+0.119</td>
<td>4.3</td>
</tr>
</tbody>
</table>

* \( p < 0.05 \). ** \( p < 0.01 \).
Disadvantaged Engineering Undergraduates

by gender was small, ranging from .1 for Whites to 1.01% for Native Americans. Given the nonsignificance of gender in the ANOVA on PES by gender and ethnicity/race, the remainder of the findings focuses on PES differences by ethnicity/race.

Figure 3 presents a comparison of median PES for students initially entering engineering versus non-engineering majors. The median PES for engineering students is within 1% of the median PES of non-engineering students when both populations are examined in the aggregate; however, Figure 3 shows that the large differences across ethnic/racial group in engineering shown in Figure 2 mirror the differences present in the overall population. The difference between median PES for White and Black students in engineering compared to those in non-engineering majors is the smallest (0.4 and 0.5, respectively), with somewhat larger gaps for Asian (0.9), Latina/o (1.3), and Native American students (–3.6). Among first-time, first-year students matriculating to MIDDLEFIELD schools between 1994 and 2003, only Native Americans choosing engineering attended less privileged high schools than their same-race peers for non-engineering majors. While the differences are small, the direction of the relationship is the same for all other ethnic/racial groups—White, Asian, Black and Latina/o students at MID-

Figure 2. Interaction Plot of Median PES for Full-Time, First-Year Students in Engineering at MIDDLEFIELD Institutions by Gender and Ethnicity/Race, 1994–2003
FIELD schools who matriculated in engineering attended slightly more privileged high schools than their same-race peers in non-engineering majors.

**Engineering Matriculants Compared to All 12th Graders, by Ethnicity/Race.** Figure 4 presents the cumulative distribution of first-time engineering matriculants at MIDFIELD schools between 1994 and 2003 compared to the median PES of 12th graders (in the CCD). Although the median PES for all incoming engineering students of 91.6% was similar to that of non-engineering students, it is more notably different from the median PES for 12th graders, which is 85.7%. First-time engineering students at MIDFIELD institutions attended high schools with lower levels of poverty than median 12th graders in the United States.

In Figure 2, it was noted that among engineering undergraduates, high school poverty is related to ethnicity/race. Figure 4 provides a clearer sense of the distribution of PES by ethnicity/race. Only 25% of White engineering students attended high schools with a PES less than 86% (the median for all 12th graders); whereas 62% of Black students attended high schools with a PES less than 86%. The median PES for historically underrepresented students entering engineering is lower than that of the typical 12th grader, 83.4%, and is significantly
lower than the median PES for majority students, 92.3 (median test, $p < 0.0001$). A review of the entire cumulative distribution reveals a maximal difference (31%) in the cumulative distribution at $PES = 87\%$. This indicates that 61% of Black, Latina/o, and Native American engineering students have a PES of 87% or less compared to only 30% of White and Asian engineering students, yielding a highly significant KS-test ($p < 0.0001$).

**Academic Preparation.** Since academic preparation (one potential measure of human capital) is related to socioeconomic status and ethnic/racial group membership (e.g., Baum & Ma, 2007; Veenstra et al., 2009), we examined differences in PES by ethnicity/race and SAT Math score. Figure 5 presents a comparison of the median SAT Math score and median PES for engineering and non-engineering majors by ethnic/racial group. Figure 5 shows an average difference of approximately 80 points in the median SAT math score for students in engineering compared to non-engineering majors for all ethnic/racial groups. Further analyses show that PES is correlated to SAT Math ($r = 0.17$ for all students and $r = 0.19$ for engineering matriculants); also PES is significantly correlated to SAT Math for all ethnic/racial groups who matriculated into engineering ranging from a correlation of 0.088 for White,
0.011 for Asian, 0.154 for Latina/o, 0.183 for Black, and 0.389 for Native American students.

Access to Engineering Degrees

To answer the third research question and contextualize access in engineering, we also explored differences in PES among students who matriculated into engineering and graduated within six years versus those who matriculated into engineering but did not graduate in engineering within six years. Using data from four cohorts (i.e., 1994/5 through 1997/8) at all 10 MIDFIELD institutions, Figure 6 presents the distribution of PES among students who matriculated in engineering by whether or not they graduated in engineering. The data show that students who started and graduated in engineering within six years had a median PES of 92.5, whereas those students who left engineering (either by changing majors or leaving the institution) or had not graduated yet had a slightly lower median PES of 91.5. The corresponding overall median PES for the 1994–1997 engineering matriculants was 92.0, yielding a small difference of only 0.5 between engineering graduates and matriculants.
Gender and Ethnicity/Race. We also examined differences in gender by ethnicity/race among students who started in engineering between 1994 and 1997 and graduated within six-years at the 10 MIDFIELD institutions. The median PES for female students who started and graduated in engineering was 91.9% compared to 92.8% for male students, a difference of less than 1%.

Figure 7 presents the cumulative distribution of PES of students who started in engineering and graduated within six years at MIDFIELD schools between 1994 and 1997 by ethnicity/race. With regard to ethnicity/race, the median PES of graduates was highest among White (93.2%), Asian (92.3%), Latina/o (89.1%), Native American (85.8%) and then Black (84.6%) students. Figure 7 also shows that among students who initially choose and then graduated in engineering, high school poverty continues to be related to ethnicity/race. For example, fewer than 50% of White and Asian, 65% of Native American and Latina/o students attended high schools with a PES less than 92.5%; however, nearly 80% of Black students attended high schools with a PES less than the population median. In other words, only 20% of Black students come from high schools with the median PES (i.e., less than 10% of students eligible for free lunch). A review of the entire cumula-
The cumulative distribution reveals a maximal difference (29%) in the cumulative distribution at PES = 88% of underrepresented minorities to Whites and Asians. 59% of Black, Latina/o, and Native American engineering students have a PES of 88% or less compared to only 30% of White and Asian engineering students, yielding a highly significant K-S-test ($p < 0.0001$).

Figure 8 presents the interaction plots of engineering graduates’ median PES by gender and ethnicity/race. In general, there was little difference by gender within the ethnic/racial group. However, the data appear to show gains in the median PES from matriculation to graduation for ethnic/racial groups with relatively lower PES values at matriculation including for Black students (both female and male), as well as Latinas. The differences in median PES (graduates—matriculates) were 1.8 for Black females, 1.6 for Black males, and 0.8 for Latinas. In addition, Native American females ($N = 8$) had a difference of 1.27 (gender breakdown not shown in Figure 8 due to small sample size), with a 93.6 median PES for graduates, a median PES comparable to Whites and Asians; this compares to 85.5 for Native American males. Due to the small sample size, this difference should be interpreted with caution.

Figure 7. Cumulative Distribution of PES by Ethnicity/Race for Students who Matriculated into Engineering and Graduated in Engineering within 6 Years, 1994–1997 Cohorts
Discussion and Implications

This research makes important contributions related to the socio-economic profile of students initially entering engineering using population data for students at 10 institutions affiliated with MIDFIELD. First, while the vast majority of students entering engineering attended relatively privileged high schools, the overall decrease in median PES between 1994 and 2003 suggests that students attending high-poverty high schools gained additional access to MIDFIELD institutions in the time period under study. In fact, our conservative estimates (i.e., only using free lunch rather than free and reduced lunch eligibility) show eight MIDFIELD institutions experienced declines in median PES, and four had significant declines (see Table 2). Although engineering major choice is rather unlikely from students attending high-poverty public high schools, MIDFIELD institutions as a group, and individually, enrolled a growing fraction of students from less well-resourced schools between 1994 and 2003.

Second, male and female students of the same ethnicity/race entering MIDFIELD schools graduate from high schools with similar levels of poverty, and yet, males disproportionately matriculate into engineering
programs (NSF, 2012). In fact, Hill et al. (2010) note that while there is a small gender difference in high-stakes math tests favoring male students, women are leaving high school increasingly well-prepared to pursue STEM majors. So despite their knowledge, skills, and abilities (i.e., human capital), women may still lack economic and/or cultural capital that would encourage their pursuit of an engineering degree. In effect, the gender gap in engineering enrollment does not appear to be due to socioeconomic issues derived from high school poverty.

Third, in terms of ethnicity/race and gender, our analysis of median PES among students who started and graduated in engineering reveals virtually no socioeconomic advantage for White, Asian, and Black male students over their female counterparts, but an advantage for Latina versus Latino students. Further, the differences in median PES for engineering graduates compared to matriculants did vary, and was highest for Black female and male students (1.85 and 1.59), moderate for Latinas (0.78), and small for White female and male students (0.33 and 0.49) as well as Asian male students (0.26). These data show that more privileged students tend to persist, and that those on the lower end of the (already high-skewed) PES distribution may need additional support. Taken with the negative difference in median PES between graduating and entering in engineering for Asian women (–0.75) and Latinos (–1.22), these data highlight the variable influence of socioeconomic status across and within ethnic/racial groups. In the aggregate, PES differences that accrue along the path to graduation in engineering are minimal for Asian (–0.1) and White students (0.5), and larger for Black (1.9), but with a negative difference for Latina/o (–1.1) and Native American (–1.4) students.

Taken together, these data reveal three important considerations. First, the analyses highlight the varying degrees of high school poverty experienced by students finishing at public high schools, as well as those entering, but also entering and graduating in engineering from MIDFIELD institutions. This suggests that issues of (de)segregation, social class, ethnicity/race, school sector, and school quality may all influence engineering pathways, and especially for students in considering MIDFIELD institutions (e.g., Horn, 2006; Lee & Wong, 2004; Massey et al., 2003; Rumberger & Palardy, 2005; Roska & Potter, 2011). Second, the range in median institutional PES among the 10 MIDFIELD schools (Table 2) highlights the need to also consider the complex interplay of college choice, recruitment and admissions, and persistence to completion at individual institutions, but also institutions in the aggregate. That students with the highest SAT Math scores in each population end up matriculating to and often completing engineering degrees is
positive. However, it suggests a more nuanced approach to admissions in engineering may be relevant to broaden participation. In fact, recent work by Hoxby and Avery (2012) suggests that there are a significant number of low-income, high-achieving students that are not recruited or applying to competitive institutions. Although that research doesn’t focus on engineering specifically, it does highlight the importance of admissions outreach and recruitment efforts in shaping college access for geographic areas and low-income students.

Finally, although we did not test a theoretical model, the results suggest that economic, human, and cultural capital are all important considerations for expanding access to engineering degree programs and completion. Economic and human capital likely play a critical role in where students attend high school (e.g., sector and poverty level), whereas cultural capital is perhaps as or more influential in how students perform in high school, and their college choice, major choice, and persistence to completion. In fact, the difference in the SAT Math score by ethnicity/race (Figure 5) among matriculants suggests a need for better college preparatory curricula in high poverty high schools. Further, the graduation rates data suggest enhanced support promoting proficiency, a sense of belonging, and completion are needed (as mentioned in Veenstra, Padró, & Furst-Bowe, 2012). Better understanding of how the human, economic, and cultural capital influence secondary outcomes, and may shift for engineering matriculation and success is necessary.

**Recommendations for Future Research**

Based on these data, there are three recommendations for future research on socioeconomic status and access to engineering. First, an expansion of this work would help better characterize the role of high school poverty in access to engineering degree programs and bachelor’s degrees over time and in additional institutional contexts. For example, more work on the relationship of PES and graduation rates can help identify individual institutional contributions to success for socioeconomically disadvantaged students. Research on socioeconomic status, engineering, and community colleges may also provide insight as to how students from high poverty secondary schools enter and fare in engineering and other STEM fields given extant research (e.g., Bailey & Morest, 2006; Dougherty & Kienzl, 2006; National Research Council, 2012). Additional work where predictive modeling is practical and appropriate may also enhance theoretical contributions to work on social class in engineering and other STEM-related research. Other popula-
tions to consider in future work include students attending private high schools, students from geographic areas not represented in MIDFIELD, and part-time students.

Second, future research exploring socioeconomic disadvantage should be conducted in conjunction with ethnicity/race and gender to build upon extant research acknowledging intersectionality and the various barriers that deter students across and within groups from engineering (Lundy-Wagner, 2012; Ohland et al., 2011). While colleges and universities with more resources are often better able to provide support necessary for student success, some research shows that even institutions with lower levels of expenditures successfully matriculate and confer engineering degrees to students from disadvantaged backgrounds (e.g., Chubin et al., 2005; Horn, 2006; Perna et al., 2009). The complex interplay between student-level academic, demographic, and attitudinal/behavioral characteristics and institution-level characteristics (i.e., structures, policies, and culture) requires more nuanced research.

Third, while this research is helpful in describing the socioeconomic profile of students, the work by Lareau and Conley (2008) cautions the use of quantitative measures of social class to explain or ameliorate qualitative experiences. As such, more research is needed to understand how institutions of higher education and engineering schools make sense of socioeconomic status in their retention policies and programs. While preliminary work has examined engineering staff adviser perceptions of socioeconomic disadvantage and how it inhibits success (e.g., Lundy-Wagner, Salzman, & Ohland, 2013), as Borrego, Douglas, & Amelink (2009) suggest, more qualitative work is needed in engineering education.

**Conclusion**

In the engineering context, access to bachelor’s degree programs and bachelor’s degrees remains a critical component for expanding the pipeline, preparing the workforce, and seeking social justice. The findings from this study support past research in the K–12, higher education, and engineering education, highlighting the relationship between school choice, high school poverty, matriculation into and graduation in engineering.

With use of the PES variable, we connect individual postsecondary student-level data to aggregate high school poverty data to characterize matriculation and subsequent graduation in engineering. Our findings show that for the period between 1994 and 2003 there was an increase in access to engineering degree programs by students from high
schools with a higher percent of students eligible for free lunch. While this is positive news, that the median PES of all 12th graders (85.7%) was noticeably lower than that of students matriculating into engineering (91.6%) confirms that students who enter college and engineering specifically, attended relatively privileged high schools. In fact, approximately 60% of engineering graduates attended high schools with a free lunch eligible population of 10% or less. In order to expand access, stakeholders must devise strategies for entry into engineering relevant for students attending high-poverty high schools specifically.

With regard to demography, there are important conclusions as well. While there appears to be no relationship between women pursuing engineering and socioeconomic status (as measured by PES), there are significant differences in PES by ethnicity/race at matriculation and graduation. These differential outcomes are worrisome and support our use of economic, human, and cultural capital to frame strategies for supporting underrepresented minorities and other disadvantaged students. Further, if relatively higher poverty schools represent less resourced schools, less proficient students, fewer expert teachers in math and science, and less academic support (as noted by Aud et al., 2011; Lee & Wong, 2004; Owens, 2010; Rumburger & Paldary, 2005), underrepresented minorities are at a clear disadvantage in applying to and navigating engineering. Despite that, it is significant, that the cumulative distribution for students graduating in engineering is about the same as for students who entered engineering, indicating that engineering colleges and the students themselves are relatively successful.

Overall, student decisions to matriculate into engineering are influenced by myriad factors, including (but not limited to) ethnicity/race, gender, socioeconomic status, and the type of high school they attended. These characteristics may represent a complex relationship of economic, human, and cultural capital, as well as concepts like intersectionality that are relevant for understanding postsecondary behavior and achievement of subgroups. That said, stakeholders must provide more opportunities for capable, interested, and motivated students to choose engineering during the secondary school years, especially for women and students attending or who attended high-poverty high schools (Hill et al., 2010; President’s Council of Advisors on Science and Technology, 2010; Saifer & McDermott, 2011). Higher education stakeholders also have a responsibility to continue promoting policies and practices from recruitment to entry that are responsive to students from high-poverty high schools in order to truly expand access to engineering degree programs and engineering bachelor’s degrees.
Note

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