The Association between Engineering Students' Perceptions of Classroom Climate and Fundamental Engineering Skills: A Comparison of Community College and University Students

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ABSTRACT

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. Previous research on the classroom climate for STEM majors suggests that women and minorities may experience a "chilly climate" and find the classroom unwelcoming; this negative climate may in turn have an impact on a student's success or persistence in attaining a degree. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering.

Data from a 2009 National Science Foundation sponsored project, *Prototype to Production: Processes and Conditions for Preparing the Engineer of 2020* (P2P), which contains information from students in 31 four-year colleges and 15 pre-engineering community college programs, were examined. After establishing measures for classroom climate and fundamental skills related to engineering through an exploratory factor analysis, results indicated that university students had higher perceptions of their fundamental engineering skills as compared to community college students. Community college engineering students, on the other hand, perceived their classroom climates as warmer than university engineering students.

In order to explore differences in student perceptions by individual characteristics and by institution, hierarchical linear modeling (HLM) was used. Results indicated that for both community college and university engineering students, a warmer perception of classroom climate was associated with a higher perception of fundamental engineering skills. For the

community college data, there was significant but low variation between schools, suggesting that student level characteristics may explain more of the variation. At the individual level, the interaction terms for gender and race were significant, indicating that the association between gender and perceptions of fundamental engineering skills depends on race. For the university students, only gender was significant, with male students reporting higher perceptions of their fundamental engineering skills. Almost all of the engineering disciplines were significant, which led to an additional HLM analysis with engineering program as the highest nested unit. Results from this model indicated that the highest percentage of variation in fundamental skills in engineering was at the program level.

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Chapter 1: Introduction

In order to compete in the global economy, producing sufficient numbers of graduates who are trained for science, technology, engineering, and mathematics (STEM) careers has become an educational priority in the United States. Compared to their peers in other Organisation for Economic Co-Operation and Development [OECD] nations, U.S. elementary and secondary students lag behind in mathematics and science performance (OECD, 2013). In higher education, the relative proportion of students majoring in STEM fields is declining (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, 2007; U.S. Department of Education, 2011). Although the U.S. continues to be a leader in technological innovation, in recent years it has faced growing competition internationally, primarily from the Asia/Pacific region (National Science Board, 2010). Domestically, nearly half of the economic growth in the U.S. is attributed to STEM fields, and over the past decade, STEM-related jobs have grown three times as fast as non-STEM jobs (Langdon, McKittrick, Beede, Khan, & Doms, 2011). It is projected that STEM job openings will continue to grow exponentially in the coming years (Langdon et al., 2011; Vilorio, 2014); at the current rate, economic projections suggest a need for approximately one million more STEM professionals in the U.S. (President's Council of Advisors on Science and Technology [PCAST], 2012).

Responding to this need for STEM workers, numerous agencies have called for an increase in the number and diversity of students pursuing STEM degrees (e.g. Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, 2007; The White House, 2009). The U.S. Department of Defense emphasized the importance of diversifying the STEM workforce, identifying this as a national security issue (National Academy of Engineering & National Research Council, 2012). In 2009, President Obama launched the “Educate to Innovate” initiative to move U.S. student achievement “from the middle to the top of the pack in science and math” and diversify participation in STEM fields (The White House, 2009, para. 2). Although this initiative is important, the concern of diversifying STEM fields is not new. For example, in 1980, Congress authorized appropriations for the National Science Foundation (NSF), through the Science and Technology Equal Opportunities Act, to support the participation of women and minorities in science and engineering (S. 568, 1980).

While the proportion of women and minority students attending college is increasing, these students do not complete STEM degrees at the same rate as their white male counterparts (Anderson & Kim, 2006; National Science Board, 2008; U.S. Department of Education, 2011; Yoder, 2014). For all undergraduates, the rate of persistence for students in STEM fields is about 50%, which is roughly the rate for non-STEM majors as well (Chen, 2013; National Science Board, 2008). However, for minority students, namely African Americans and Hispanics, the likelihood of completing a STEM degree is much lower (Anderson & Kim, 2006; National Science Board, 2008); as a result, there are fewer minority students graduating in STEM programs relative to their proportion in the undergraduate population—11% vs. 30% respectively (Anderson & Kim, 2006; National Science Board, 2008). Similarly, although women currently outnumber men in terms of undergraduate degree attainment (Davis & Bauman, 2011), women are less likely to major in a STEM field and even when they do, they are less likely to obtain a job in STEM (Diekman, Brown, Johnston, & Clark, 2010; Wang & Degol, 2013).

In the engineering area of STEM, women and minorities are particularly underrepresented (Beede et al., 2011; Yoder, 2014). A recent report by Yoder (2014) showed that only 19.5% of engineering bachelor’s degrees are awarded to women; overall women are awarded more than half of bachelor's degrees (Aud et al., 2012). In certain disciplines of engineering, the ratio of men to women is even more lopsided; for example, only 12.0% of computer engineering degrees are conferred to women (Yoder, 2014). On the other hand, some disciplines, such as environmental engineering with 48.0% women, are more balanced. In terms of ethnicity, about 66% of engineering bachelors' degrees are awarded to white students, followed by Asian-American students with about 13% (Yoder, 2014); Hispanic students make up about 10% of engineering bachelor's and African-American students make up 3.5% (Yoder, 2014).

Diversifying the field of engineering in terms of gender and race/ethnicity is important for many reasons. In the National Academy of Engineering's report on the future of engineering education, the authors acknowledge that "the success of engineering is based on a deep reservoir of talented people. In the United States this wellspring has been nourished principally by drawing from a white male population"; however, for the engineers of 2020, they continue, "we aspire to an engineering profession that will effectively recruit, nurture, and welcome underrepresented groups to its ranks" (National Academy of Engineering, 2004, pg. 50). Pragmatically, as the U.S. population continues to become more racially diverse, with an estimated 57% of the population in 2060 projected to be minorities (U.S. Census Bureau, 2012), currently underrepresented groups will be needed for engineering jobs. Beyond this, though, racial and gender diversity allows for more perspectives when solving problems, which could lead to more innovative solutions (Hoever, van Knippenberg, van Ginkel, & Barkema, 2012). Studies outside of the engineering field have shown that heterogeneous teams can have positive effects on creativity, satisfaction, and team-member well-being (Stahl, Mäkelä, Zander, & Maznevski, 2010). In higher education, structural diversity has demonstrated positive outcomes for students in terms of their self-concepts, both academically and socially (Pascarella & Terenzini, 2005).

Researchers have suggested a variety of reasons underrepresented groups do not initially choose engineering majors or persist in completing an engineering degree (e.g. Blickenstaff, 2005; Hill, Corbett, & St. Rose, 2010**;** May & Chubin, 2003). In high school, female students tend to graduate having taken fewer Advanced Placement (AP) STEM exams, such as calculus and physics (The College Board, 2009); female students who do take AP exams in these subjects tend to score lower than males (The College Board, 2009; Niederle & Vesterlund 2010), giving male students a head start in terms of college credit when entering college. Although females tend to choose engineering majors at a much lower rate than male students—13% versus 28% respectively (NSF, 2009)—of the female students who do enter college as engineering majors, they tend to be equally prepared, having taken and earned similar grades in the prerequisite math and science courses (Huang, Taddese, Walter, & Peng, 2000). Although academically capable, many female students leave engineering majors early in their college careers (Blickenstaff, 2005; Brainard, & Carlin, 1997). One possible explanation for this is the lack of female engineering role models in general, and in particular at the university level (Blickenstaff, 2005; Yoder, 2014). Of all engineering faculty members in the 2013-2014 school year, 85% were male and 15% were female (Yoder, 2014), which could influence female students' persistence in engineering (Sonnert, Fox, & Adkins, 2007). Another possible explanation for female attrition rates is the classroom climate that some female students feel is less welcoming for them (Janz & Pyke, 2000; Morris & Daniel, 2008; Pascarella et al., 1997; Sandler, Silverberg, & Hall, 1996; Whitt, Edison, Pascarella, Nora, & Terenzini, 1999); the idea of a "chilly" classroom climate is explored further in Chapter 2 of this dissertation.

Minority students, particularly Hispanic and African American students, face additional challenges when pursuing engineering degrees. In high school, African American and Hispanic students tend to perform lower than white and Asian American students in the foundational engineering courses of math and science (Hill et al., 2010; May & Chubin, 2003). Hispanic and African American students also take fewer advanced math and science courses as compared to white and Asian American students (Hill et al., 2010; May & Chubin, 2003; Taningco, Mathew, & Pachon, 2008), making it more difficult to successfully complete an engineering degree in college (Hill et al., 2010). Additionally, similar to female students, racial and ethnic minority students do not have many engineering role models in the media or at the university level (May & Chubin, 2003; Yoder, 2014). In 2013, African Americans made up 2.5% of engineering university tenure and tenure-track faculty members while Hispanics comprised 3.9% (Yoder, 2014). African American and Hispanic students who do begin an engineering degree may perform poorly on exams simply because of stereotype threat, or a fear of conforming to an existing stereotype (Steele, 1997); this concept is described in more detail in Chapter 2 of this dissertation as it serves as a conceptual framework for the study.

Although there have been many efforts to increase the proportion of underrepresented groups in engineering (e.g. Felder, Brent, & Prince, 2011; The White House, 2009; Yelamarthi, & Mawasha, 2008), these students continue to be untapped potential for engineering workforce needs. This underrepresentation is occurring at a time when the majority of growth in U.S. college enrollment is expected to come from minority students attending community colleges, a focus of this dissertation. In the fall of 2011, over 45% of all undergraduates were enrolled in a public, two-year community college (Knapp, Kelly-Reid, & Ginder, 2012). Among all undergraduates, community colleges enroll 41% of first time freshman, 57% of Hispanic undergraduates and 52% of African American undergraduates (American Association of Community Colleges [AACC], 2015b); of the students enrolled in community colleges, 57% are women (AACC, 2015b). In engineering, community college transfer students comprise an estimated 12% and 17% of the engineering bachelor's degrees conferred (Terenzini, Lattuca, Ro, & Knight, 2014). In his 2015 State of the Union address, President Barack Obama emphasized his support of community colleges by introducing a plan for free tuition at community colleges, "so that two years of college becomes as free and universal in America as high school is today" (The White House, 2015).

Community colleges may provide a realistic pathway for underrepresented students to earn an engineering degree, however, there are challenges with this pipeline as well (Mattis & Sislin, 2005; Packard, Gagnon, & Senas 2012). Articulation agreements, which allow for simplified transfers between community colleges and four-year institutions, are in some cases weak, or non-binding and therefore less effective (Mattis & Sislin, 2005). Community college students may also lack the math background needed for successful transfer to a four-year engineering program, and may not be able to find courses at the community college that will allow them to reach the level of proficiency needed (Dimitriu & O'Connor, 2004). Along with the lack of preparation, many community college students are part-time and/or are working while taking classes (AACC, 2015b), making the time to complete an associate's degree longer than two years, and subsequently making the bachelor's degree take longer as well (Alfonso, 2006; Hoachlander, Sikora, Horn, & Carroll, 2003).

Problem of the Study

Currently, there is a need for more STEM majors, and in particular engineering majors, in order to meet projected workforce needs (PCAST, 2012). Diversifying the field of engineering, in terms of gender and race/ethnicity, is one way to meet this need, as well as provide more perspectives in the field. While the proportion of women and minority students attending college is increasing, these students do not tend to choose or persist in engineering majors at the same rate as white male students (Anderson & Kim, 2006; National Science Board, 2008; U.S. Department of Education, 2011; Yoder, 2014). Given that community colleges are comprised of 57% female students, 14% African Americans, and 21% Hispanics (AACC, 2015b), these institutions may provide an important pathway for underrepresented groups in engineering. However, research in the area of community college engineering programs is limited (Laanan, Jackson, & Darrow, 2010; Ogilvie, 2014).

Purpose of the Study and Research Questions

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. Previous research on the classroom climate for STEM majors suggests that women and minorities may experience a "chilly climate" and find the classroom unwelcoming (Hall & Sandler, 1982; Janz & Pyke, 2000; Morris & Daniel, 2008; Pascarella et al., 1997; Sandler et al., 1996; Whitt et al., 1999); this negative climate may in turn have an impact on a student's success or persistence in attaining a degree. As such, it is important to study what occurs at the classroom level in engineering in terms of how women and minority students are treated. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering. The study was guided by the following research questions:

1a. What are community college engineering students' perceptions of their classroom climate and fundamental engineering skills?

1b. What are university engineering students' perceptions of their classroom climate and fundamental engineering skills?

1c. How do community college engineering students' perceptions of their classroom climate and fundamental engineering skills compare to and/or differ from university engineering students' perceptions?

2a. How are community college engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

2b. How are university engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

Overview of Methodology

To address these research questions, data from a National Science Foundation sponsored project, *Prototype to Production: Processes and Conditions for Preparing the Engineer of 2020* (P2P) were examined. These data were collected in 2009 from a nationally representative sample of engineering undergraduates, alumni, faculty, program chairs, and associate deans from 31 four-year colleges and universities and from 15 pre-engineering community college programs. The purpose of the original study was to examine the curricular and co-curricular experiences of engineering students in order to understand if students were gaining the knowledge and skills needed for success in the workforce, as identified by the National Academy of Engineering.

In the current study, survey data from engineering undergraduates at four-year colleges and universities and from pre-engineering undergraduates at community colleges were used. In addition to demographic information, the items related to self-rated fundamental skills in engineering and perceptions of classroom climate were analyzed. These survey instruments were developed by engineering and education researchers through a two year process which included literature reviews on the topic, individual interviews, focus groups, and pilot testing of the instruments.

In order to answer the first research question, measures of classroom climate and fundamental skills in engineering were established through the use of exploratory factor analysis (EFA). An EFA, a data reduction technique used to identify latent variables (Brown, 2006; Rencher, 2002), was conducted on both the community college and university students surveys in order to define the latent constructs on the instruments. Resulting scales from these EFAs were then used in the hierarchical linear modeling (HLM) analyses. Because there were slight differences in the wording of the items on the community college and university student instruments, in order to compare the results between the groups, it was necessary to linearly equate the scores on the two instruments (Kolen & Brennan, 2014). After equating the scores from each instrument, the results were compared descriptively. To answer the second research question, HLM was used in order to explore differences in student perceptions by institution and how these perceptions may influence their fundamental skills in engineering. HLM was chosen because of the interest in institutional differences in addition to individual differences (Raudenbush & Bryk, 2002).

Organization of Dissertation

This dissertation is organized around five chapters. Chapter 1 introduced the relevance of the topic, the purpose and research questions for the study, and gave an overview of the methodology. Chapter 2 is a review of the literature on the topic, including three main topic areas (1) Classroom Climate in Higher Education, (2) Community College Pre-Engineering Students, and (3) Background Characteristics of Engineering Students. Chapter 2 also includes a description of the conceptual frameworks that support the study. Chapter 3 describes the methodology, including the analytic approach, demographic information for the sample, as well as initial descriptive statistics. Chapter 4 includes the results of the study, organized by research question. In the final chapter of the dissertation, Chapter 5, the discussion, conclusions, and implications are presented along with areas for future research.

Chapter 2: Literature Review

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering. Chapter 2 beings with a description of the conceptual framework that informs this study followed by a review of relevant literature. The review of literature is organized around three main topic areas: (1) Classroom Climate in Higher Education, (2) Community College Pre-Engineering Students, and (3) Background Characteristics of Engineering Students.

Conceptual Framework

The conceptual framework for this study was informed primarily by two frameworks: (1) Steele and Aronson's (1995) concept of stereotype threat and (2) Terenzini and Reason's (2005) conceptual framework for studying student learning and persistence in college. Together, these frameworks supported the study both conceptually and methodologically. Steele and Aronson's (1995) notion of stereotype threat served as a foundation to explore the relationship between classroom climate and student rating of fundamental skills in engineering, the focus of this study. Terenzini and Reason's (2005) conceptual framework supported the methodological concerns regarding predictive and control variables to include in the statistical models.

Stereotype Threat

Steele and Aronson (1995) first defined stereotype threat as "being at risk of confirming, as self-characteristic, a negative stereotype about one's group" (p. 797). This concept was supported by a series of studies in which black and white students were given standardized test questions from the Graduate Record Exam (GRE). Prior to starting the tests, students were divided into three groups. One group was told that the purpose of the test was a diagnostic measure of their intellectual ability, thus establishing a threat for black participants who were at risk for fulfilling a racial stereotype about intellectual ability. Another group was told the test was a problem-solving task that was non-diagnostic, and a third group was told to view the difficult test as a challenge. When prompted that the test was a diagnostic measure of intellectual ability, i.e. the stereotype threat condition, black students preformed significantly lower than white students. Under the other two conditions, i.e. the non-stereotype threat conditions, there were no significant differences between black and white students.

Steele (1997) furthered his work by describing how domain identification compounds the effects of stereotype threat. In order for students to maintain success in school, they must first be positively identified with academics, such that it is part of his or her personal identity—a concept known as domain identification. Certain students, such as math-identified women, may have already overcome societal obstacles in order to achieve identification with a domain. As Steele explains,

> Negative stereotypes about women and African Americans bear on important academic abilities. Thus, for members of these groups who are identified with domain in which these stereotypes apply, the threat of these stereotypes can be sharply felt and, in several ways, hampers their achievement. (1997, p. 614).

As described earlier, if a threat occurs during a domain performance, such as a standardized test, stereotype threat could directly interfere with performance. If this threat becomes chronic, a student could be pressured into disidentification, or removing the domain from his or her self-identity. In other words, a math-identified female student, who continually faces a male-oriented math environment, may eventually remove math from her domain identification and choose another area of study.

To mitigate the effects of stereotype threat, Steele (1997) provided several suggestions for college classroom settings. For one, he suggested a teacher-student relationship in which teachers use their authority to positively affirm the student's potential. He also suggested that teachers provide all students with challenging assignments, rather than remedial ones, which reinforce to the student that he or she has potential and is not viewed through a stereotypical lens. Steele also suggested that instructors emphasize the "expandability of intelligence," meaning that there is no fixed intelligence intrinsic to one's group. Lastly, Steele recommended that instructors value multiple perspectives in the classroom in terms of both academic substance and culture (Steele, 1997).

The notion of stereotype threat was predicated by several important studies, supporting similar concepts. For example, in their study on IQ tests, Katz, Epps, and Axelson (1964) found that black students performed better when they were told their scores would only be compared to other black students as opposed to white students. Similarly, Katz, Roberts, and Robinson (1965) found that black participants performed better on IQ tests when they were told the test measured hand-eye coordination, rather than intelligence. These studies, however, were both conducted in the 1960's, a tumultuous decade for race relations in the U.S. With a slightly different focus, Lord and Saenz (1985) found that having "token" status in a group, or being the only minority in a homogenous group, can lead to deficits in cognitive functioning and memory. For stereotype threat to have an effect, a student does not have to have "token" status. However, in many fields in which minority groups are underrepresented, students may experience both "token" status and stereotype threat.

Terenzini and Reason's Conceptual Framework

Terenzini and Reason's (2005) conceptual framework for studying student learning and persistence in college was developed for students in their first year of college, but has been adapted for use in researching the effects of college throughout a student's experience in college. This framework is informed by previous research and theories on college impact, including Astin (1985, 1993), Tinto (1975, 1993), Pascarella (1985), and Berger and Milem (2000). While these college impact models were useful in understanding several areas affecting student outcomes' in college, Terenzini and Reason (2005) concluded that these models were too narrow, and offered a more comprehensive conceptual framework for studying student outcomes.

Terenzini and Reason's (2005) framework, shown in Figure 1, integrates four sets of constructs thought to influence student outcomes: (1) student precollege characteristics and experiences, (2) the organizational context, (3) the student peer environment, and (4) the individual student experience (Terenzini & Reason, 2005). In the first construct, Terenzini and Reason assert that students enter college with a range of characteristics and experiences, including varying sociodemographic traits (e.g. gender, race/ethnicity, and/or family income), academic preparation and performance (e.g. the quality of their high school curriculum), personal and social experiences (e.g. involvement in their communities), and their dispositions (e.g. motivation). These precollege characteristics and experiences shape students' interactions with their environment, and peers and faculty in that environment, in college.

In the next construct—the organizational context—Terenzini and Reason describe the organizational characteristics and cultures that students encounter at an institution. In their conceptual framework, the organizational context is divided into three categories: (1) internal structures, policies, and practices, (2) academic and co-curricular program policies and practices, and (3) the faculty culture. Internal structures, policies, and practices can include management style, staff support available for various units, and/or the nature of collaboration among faculty members and students. Examples of academic and co-curricular program policies and practices include a common general education curriculum, living-learning communities, service-learning courses, and a new student orientation program. Faculty culture, as described by Terenzini and Reason (2005), “consists of the dominant philosophies of education to which most (or a significant number of) faculty members subscribe, as well as their perceptions of their roles and what it means to be a faculty at ‘this’ institution” (p.10).

The third construct in the conceptual framework is the student’s peer environment at the institution. Terenzini and Reason point out that peer environment goes beyond a student’s individual interaction with other students or with students in his or her peer group. Rather, the peer environment encompasses the dominant beliefs and values that characterizes the whole student body at the institution that are “more easily sensed than measured” (Terenzini & Reason, 2005, p.11). The last construct, individual student experiences, includes students’ curricular (e.g. choice of major, coursework), classroom (e.g. type of pedagogies exposed to, faculty feedback), and out-of-class experiences (e.g. living arrangements, involvement in co-curricular activities, family support).

Together, this conceptual framework “is intended to identify the broad array of factors and some of the possible causal mechanisms that influence the kinds of experiences [students] have on a campus and the attendant educational outcomes” (Terenzini & Reason, 2005, p.13). The framework does not specify the educational outcomes in particular, but rather is intended to be flexible for use many college student outcomes, such as student learning, development, change, and persistence.

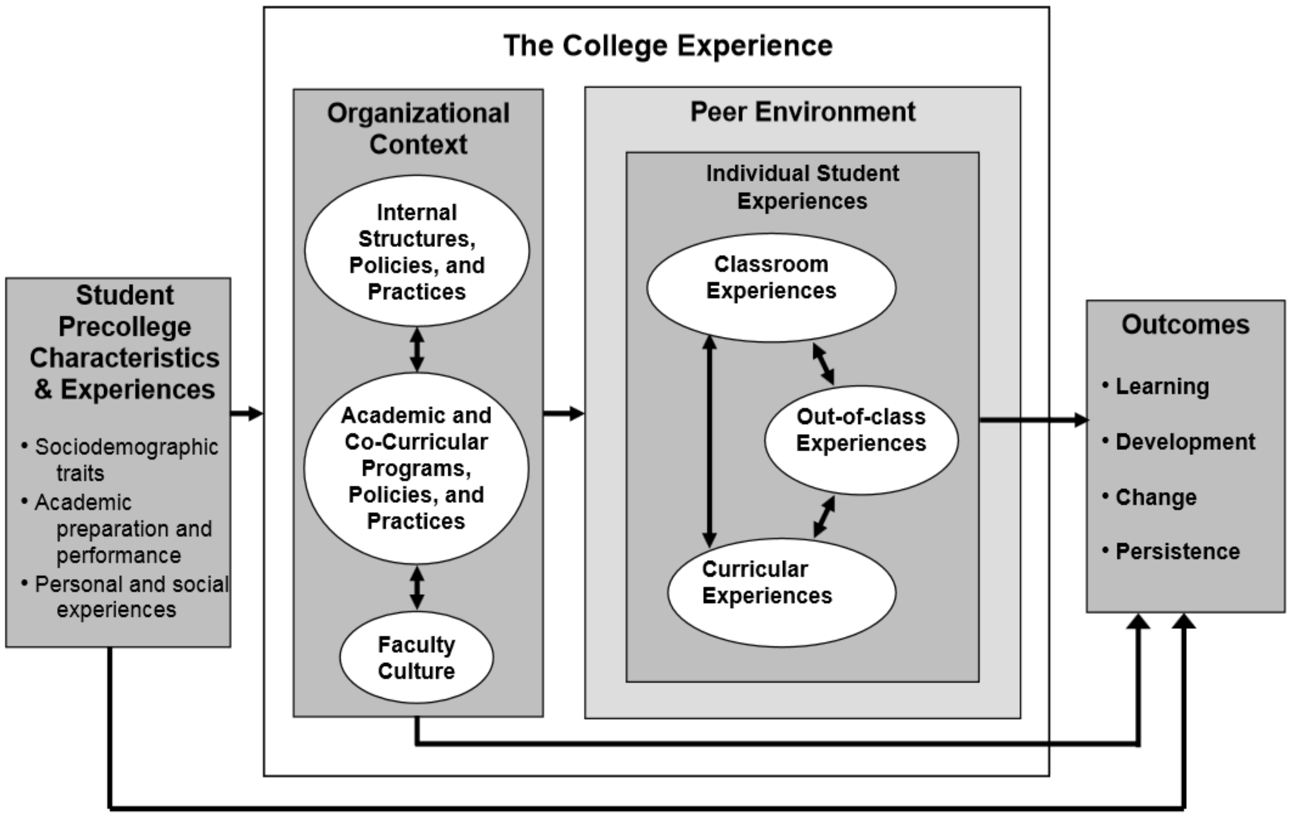

Figure 1. Terenzini and Reason's (2005) conceptual framework.

Classroom Climate in Higher Education

At every level of education, the classroom is an important learning environment for students and thus an important area of study. For community college students in particular, who typically attend commuter campuses, the classroom serves as one of the primary settings in which they interact with faculty and with other students. For all students in higher education, positive, validating experiences inside, as well as outside, the classroom can lead to student engagement and ultimately persistence to a degree (Pascarella & Terenzini, 2005). In this study, classroom climate refers to how students, primarily women and minority students, are treated in the classroom by their instructors and peers.

At colleges and universities, some women and minorities have described the academic and social climate as isolating and exclusionary (e.g. Hall & Sandler, 1982; Hall & Sandler, 1984; Janz & Pyke, 2000; Morris & Daniel, 2008; Pascarella et al., 1997; Whitt et al., 1999). For women in particular, Hall and Sandler published a report in 1982 describing a "chilly climate" that women face subtly and overtly in the university classroom. As Hall and Sandler (1982) point out, "a chilling classroom climate puts women students at a significant educational disadvantage" (p. 3) by possibly discouraging their participation in class, preventing women from seeking help outside of class, or causing students to drop out of or avoid certain classes. Some of the overt ways that women and men are treated differently in university classrooms include: devaluing a woman's accomplishments by attributing her success to luck; making disparaging comments about women by questioning her seriousness and academic commitment; making sexist jokes; diverting discussion of a woman student's work to a discussion of her physical appearance; referring to males as "men" and females as "girls"; and downplaying scholarship and research about women (Hall & Sandler, 1982).

More subtle ways that women and men are treated differently in the classroom include: making eye contact with men more often than women; nodding and gesturing more often to affirm men's questions and comments; calling more often on men than women; interrupting women students more often; and asking women students questions that require lower order thinking, such as factual questions, while asking men questions that require higher order thinking skills. For minority women, these negative classroom experiences may be exacerbated as they face stereotypes based on their gender and race. Minority students reported similar subtle and overt behaviors by faculty mentioned earlier, such as faculty: ignoring; interrupting; avoiding eye contact; offering little guidance; and attributing their success to luck or other factors rather than ability (Hall & Sandler, 1982).

In a follow-up report, Hall and Sandler (1984) expand their chilly climate concept to include the campus climate, defined as interactions with other students and staff outside of class, students' experiences with support services such as financial aid, and student government and leadership. Again, they report that women experience a chilly climate at universities; for example, in career counseling, marriage and family are viewed as negatives for women, whereas for men, they are seen as a symbol of maturity. Hall and Sandler (1984) conclude "the hidden or not-so-hidden message women too often receive from faculty, staff and fellow students is that they are not on the same level as their male peers, and are 'outsiders' on campus. Because these messages seem so 'normal,' they may be almost invisible to those who send and those who receive them" (p. 3-4).

Since Hall and Sandler's initial report in 1982, the proportion of women attending college has remained above 50% (approximately 52% in 1982 and 57% currently); however, many studies continue to support the notion of a chilly classroom climate for women and minorities at universities (Janz & Pyke, 2000; Morris & Daniel, 2008; Pascarella et al., 1997; Whitt et al., 1999). Pascarella et al. (1997) studied female students' perceptions of a chilly climate and how this might affect their cognitive outcomes in the first year of college. The researchers used the Perceived Chilly Climate for Women Scale (PCCWS), which included eight Likert-scale items, to measure the students' perceptions. Twenty-three institutions participated in the survey, including 18 four-year institutions and five two-year institutions. At both four-year and two-year institutions, the perception of a chilly climate was negatively associated with self-reported gains in academic preparation for a career. At two-year institutions, a perception of a chilly climate was also negatively associated with cognitive development at the end of the first year (Pascarella et al., 1997).

Whitt et al. (1999) conducted a follow-up study to Pascarella et al.'s (1997) study in order to determine the association between a chilly climate and women's cognitive growth during the second year of college; in this study, the same sample of women were surveyed. Results indicated that for the two-year college students, perceptions of a chilly climate were associated negatively with three cognitive outcomes in their second year: self-reported gains in writing and thinking skills, understanding science, and understanding the arts and humanities. For the four-year students, perceptions of a chilly climate were associated negatively with those three cognitive outcomes, as well as, academic preparation for a career (Whitt et al., 1999). The researchers suggest that a possible explanation for the differences found between the two- and four-year students were due to the PCCWS instrument. The PCCWS emphasized the climate issues in the classroom setting, rather than the rest of campus; two-year college students may associate climate more so with the classroom as this is their primary college experience (Whitt et al., 1999).

Believing that existing measures of a chilly climate needed improvement, Janz and Pyke (2000) developed a new instrument called the Perceived Chilly Climate Scale (PCCS). After pilot testing and item analysis, the final PCCS instrument consisted of 28 Likert-scale items measuring four constructs: (1) climate students hear about, (2) sexist attitudes and treatment, (3) climate students experience personally, (4) classroom climate/course material, and (5) safety. Distributing the PCCS to 488 undergraduates, results indicated that women, students who identified as minorities, and students who identified as feminists perceived the climate as significantly "chillier" (Janz & Pyke, 2000).

Using the PCCS instrument developed by Janz and Pyke (2000), Morris and Daniel (2008) examined the chilly climate perceptions of students in traditionally female-dominated majors, such as nursing and education, and compared them to students in traditionally male-dominated majors, such as information technology and engineering. A total of 403 students attending one community college responded to the PCCS survey. After analyzing the data through canonical correlation, the researchers found that women perceived a chillier climate than men, non-white students perceived a chillier climate than white students, and younger students perceived a chillier climate than older students. Furthermore, students in traditionally female-dominated majors perceived a chillier climate than students in traditionally male-dominated majors. Morris and Daniel (2008) attributed the last finding to possible personality differences between students that lead to a certain choice of major.

Although many studies since Hall and Sandler's 1982 report have shown evidence of a chilly classroom climate, some research supports contradictory findings (e.g. Brady & Eisler, 1999; Constantinople, Cornelius, & Gray, 1988; Crawford & MacLeod, 1990; Drew & Work, 1998; Salter, 2003; Serex & Townsend, 1999). For example, Constantinople et al. (1988) and Crawford and MacLeod (1990) found no significant differences in male and female students' perceptions of classroom climate, both studies suggesting that other factors, such as class size, were more important in determining student participation. Furthermore, Salter (2003) explored the interaction between learning style, educational climate, and gender. Results indicated that perceptions of classroom experiences were associated with the interaction of these variables rather than solely with gender (Salter, 2003).

Serex and Townsend (1999) examined students' perceptions of classroom climate in four different majors, including accounting, education, engineering, and nursing. Findings revealed no significant differences in male and female students' perceptions of classroom climate. Education and nursing students, however, did perceive their classrooms as warmer than accounting and engineering students (Serex & Townsend, 1999). Analyzing a large dataset (n = 15,960) of student responses on the *College Student Experiences Questionnaire,* Drew and Work (1998) concluded that female students did not experience a chilly climate "probably due to the fact that such a climate does not exist extensively in higher education" (p. 552).

Allan and Madden (2006) sought to explore these discrepancies in findings over the existence of a chilly climate for women; more specifically, they were interested in whether the methodology used in studies of classroom climate yield different results. Employing both qualitative and quantitative methods, the researchers collected data from female juniors and seniors in six fields of study at a research university. Results indicated that methodology and interpretation of findings might lead to different conclusions regarding classroom climate. For example, from their quantitative frequency analysis, they found that 25% of female students at that university experienced chilly classroom climates; however, using the mean values derived from scales measuring aspects of classroom climate, they found that a chilly classroom climate was rare at that university. Interpreting the qualitative data from focus groups and open-ended survey questions, on the other hand, indicated that chilly classroom climates were common and that the magnitude of the problem was large (Allan & Madden, 2006).

Explaining the discrepancy in their findings, Allan and Madden (2006) suggest that a researcher's conceptual framework may lead to different interpretations of results as well as different decisions during analysis. In their study, the researchers acknowledge that they had to make a decision about what constituted a chilly climate score, which in their study was any student who chose a response other than "rarely." This lead them to conclude that, from the quantitative results, a majority of students did not experience a chilly climate; however, as they point out a troubling 25% of the students still experienced a chilly classroom climate. They further caution that in studies of classroom climate, participants may not question established gender norms in society, suggesting that this "lack of critical consciousness related to gender norms and sex inequality creates a dilemma in drawing conclusions from data analyzed via surveys or focus group discussions" (p. 703).

Classroom Climate in Engineering

Engineering classrooms are often characterized as male-normed and competitive, in some cases so much so that they are seen as "weed-out" systems (Seymour & Hewitt, 1997). A traditional introductory engineering class at a research university is likely to be large and lecture-based, which some students may not respond well to (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). For some students, this type of environment may feel unwelcoming, leading them not to choose engineering initially or not persist once they start (Morris & Daniel, 2008; Serex & Townsend 1999; Seymour & Hewitt, 1997). As noted earlier, Morris and Daniel (2008) found that in their study on the classroom climate of community college students, women and non-white students experienced a chilly classroom climate in male-dominated majors, including engineering and information technology. While Serex and Townsend (1999) did not find any gender differences in their study, they did find that students in engineering and accounting perceived their classrooms as chillier than students in education and nursing.

Vogt, Hocevar, and Hagedorn (2007) investigated factors, such as discrimination, which may influence a female student's performance in engineering. Researchers surveyed male and female students from four large, top-tier research universities on several dimensions related to performance. Nine items measuring perceived discrimination were included on the survey; the items were generally related to: (1) male peers treating females as equals; (2) male research/teaching assistants producing feelings of inferiority; (3) students having more discouragement in interactions with their male professors; (4) professors treating all students equally; (5) students made to feel inferior by male professors; (6) students feeling uncomfortable asking male faculty about coursework; (7) males having an advantage; (8) professors making less time outside of class for females than for male peers; and (9) male faculty seeming supportive of female students in the engineering program. Results indicated that females reported higher discrimination than males, as the researchers predicted. Specifically, female students felt that their male peers did not respect them as equals and that males had an advantage in engineering. Although they reported greater perceived discrimination, this did not affect the female students' self-efficacy (Vogt et al., 2007).

In order to improve attitudes about diversity in engineering classrooms, Bennett and Sekaquaptewa (2014) developed and tested an egalitarian social norms message that was orally presented to students at the beginning of the semester. At the end of the semester, both students who received this egalitarian social norms message and those who did not were invited to respond to a survey about diversity in engineering classrooms. Compared to males in the control condition, males who received the egalitarian message had more positive attitudes regarding diversity in engineering and were more likely to speak out against racist behaviors in class and in the working groups. The researchers suggest that setting an egalitarian tone at the beginning of engineering students' college careers could improve the classroom environment for students (Bennett & Sekaquaptewa, 2014).

Walton, Logel, Peach, Spencer, and Zanna (2015) also attempted to improve the climate for women in engineering classrooms by testing two brief interventions in a randomizedcontrolled trial. Participants in the study included three successive cohorts of freshman engineering students at a selective university. One intervention, the social-belonging intervention, emphasized that both men and women worry about their social belonging at first in engineering, but eventually feel welcome. This intervention provided students with a nonthreatening narrative to interpret occurrences of adversity. The other intervention group, the affirmation-training intervention, emphasized how upperclassmen in engineering learn to incorporate broader aspects of their self-identity in their daily lives as a way to manage stress. Results were compared for students who were in male-dominated engineering majors, defined as being less than 20% female students, and gender-diverse engineering majors, defined as being more than 20% female. Findings indicated the most positive results for women in male-dominated majors, who at first reported feeling more overwhelmed by daily adversities, anticipated less success, and performed worse in class than males. For these women, both interventions raised engineering GPAs over the course of the year and led them to view daily adversities as more manageable and improved their academic attitudes (Walton et al., 2015).

Methodological Concerns with Studying Classroom Climate

In studying classroom climate, there are several important methodological issues to consider. Oftentimes in classroom studies, researchers are interested in whether some aspect of the classroom, such as the teacher or the climate, contributes to a certain student outcome, such as academic achievement or self-concept. In other words, the researcher is interested in whether characteristics at the group level, or level-2 in multilevel modeling terms, have an effect on the individual level, or level-1, beyond what can be explained by the individual characteristics of the student alone. In many of these studies, the classroom-level constructs are based on aggregated student-level ratings of the classroom as these are easier to obtain than through classroom observation or other techniques. As such, in classroom climate studies, it is especially important to consider the level of analysis, the reliability of aggregated student ratings, and centering techniques (Ludtke, Robitzsch, Trautwein, & Kunter, 2009; Marsh et al., 2012; Morin, Marsh, Nagengast, & Scalas, 2014).

As Ludtke et al. (2009) suggest the first consideration in choosing the appropriate level of analysis is conceptual and depends on the research question; that is, whether the researcher is interested in the differences between students or between learning environments. If the researcher is interested in differences between students, then the student ratings of the environment might be correlated with different cognitive or behavioral outcomes of the individual. In contrast, if the researcher is interested in the differences between learning environments, the individual student ratings are aggregated at the classroom level and used to assess group-level constructs. In this scenario, the individual students "are regarded as informants on their learning environment, in the sense of multiple observers providing data on one construct" (Ludtke et al., 2009, p.122). In this dissertation, the focus was on group-level differences.

After determining the appropriate level of analysis theoretically, the researchers should then analyze the psychometric properties of the aggregated student ratings in order to determine if these ratings are measuring the intended construct (Ludtke et al., 2009). Before aggregating student perceptions of classroom climate at the class level, the researcher should determine if the difference in student responses varies within or across classes; if so, the aggregation of the variable is supported. One way of showing this is through the calculation of the intraclass correlation (ICC) (Raudenbush & Bryk, 2002) defined as:

$$ICC = \frac{\tau^2}{\tau^2 + \sigma^2}$$

where τ^2 is the variance between classes and σ^2 is the variance within classes. The ICC is the proportion of total variance that can be attributed to between-group differences, or an effect size measure of the extent to which individual ratings are affected by the learning environment.

Another consideration in multilevel modeling of classroom climate is the use of centering techniques. These techniques are simple transformations of variables that affect the substantive interpretation of results and computational issues, such as multicollinearity. There are three centering options: (1) natural or no centering, in which the raw score of the independent variables are used, (2) group mean centering, in which the group mean of the independent variable is subtracted from the raw score, and (3) grand mean centering, in which the grand mean of the independent variable is subtracted from the raw score (Raudenbush & Bryk, 2002). Group mean centering is often used in contextual effects modeling when the research focus is on differentiating between- and within- group differences. Grand mean centering is used when the research focus is comparing the adjusted means of the variables. In this dissertation, group mean centering was used in order to determine the effects of between- and within- group differences in climate on student perceptions of abilities.

Community College Pre-Engineering

Community colleges, which offer two-year technical associate's degrees, transfer degrees or transfer credits, enroll approximately 46% of all U.S. undergraduates (AACC, 2015b). In 2000, community colleges enrolled around 5,700,000 students and currently community colleges enroll over 8,000,000 students, showing significant growth (AACC, 2015b). Since 2010, community colleges have shown a slight decline in enrollment, likely corresponding to the improvement in the economy (AACC, 2015a). Of students enrolled in community college, high percentages are from underrepresented groups—57% of all Hispanic students, 52% of all black students, and 41% of all low-income students (AACC, 2015b; Knapp et al., 2012; Mullin, 2012). Traditionally, public community colleges maintain an open enrollment admissions policy, allowing for access to higher education for a wide variety of students, typically at a lower cost than a traditional four-year college or university (i.e. the average cost of one year of public community college is $3,300, compared to $9,100 at a four-year public university [The College Board, 2015]). Given that community colleges are comprised of 57% female students, 14% African Americans, and 21% Hispanics (AACC, 2015b), these institutions may provide an important pathway for underrepresented groups in engineering. In engineering currently, it is estimated that between 12% and 17% of students who earn a bachelor's degree in engineering began their degrees at community colleges before transferring to a four-year institution (Terenzini et al., 2014). An even larger percent—approximately 40%—of students who earn a bachelor's degree in engineering report attending a community college at some point in their education (AACC, 2014).

In a descriptive study, Terenzini et al. (2014) compared engineering students at community colleges, students who transferred into a four-year engineering program, and traditional four-year engineering students. Using the same dataset as the one in this dissertation, Terenzini et al. (2014) found several important differences among the groups, both in terms of their background characteristics as well as their experiences in college. Compared to the traditional four-year students, community college and transfer students were more likely to be a member of an underrepresented group (such as African American or Hispanic American) and less likely to be women. They also found that, on average, community college and transfer students were two years older than traditional students and expected that earning their bachelor's degree in engineering would take five to six years longer than traditional students. In terms of academic preparation in high school, community college students self-reported earning grades in the “B-minus” to “B” range, transfer students reported grades in the “B” to “A-minus” range, and traditional students reported high school grades in the “A-minus” to “A’ range. Once in college, a majority of the community college students (78%) and over half of the transfer students (56%) had to complete a lower-level math course before taking a college-level calculus course (Terenzini et al., 2014).

In a longitudinal study of engineering transfer students, Sullivan et al. (2012) reported characteristics and educational outcomes of transfer students compared to non-transfer students. For their analysis, Sullivan et al. (2012) used data from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), a census of undergraduate students attending 11 public institutions between 1988 and 2008. Results indicated that engineering transfer students were more likely to come from underrepresented minority groups and less likely to be women. Furthermore, results indicated that on average non-transfer students outperform transfer students and non-underrepresented minority students outperform underrepresented minority students in terms of persistence and GPA. However, the researchers found that underrepresented minority transfers, especially black transfer students, were more likely to persist than non-transfer underrepresented students and had a higher six year graduation rate, indicating that the transfer pathway into engineering may be effective for these students. Transfer women in the study preformed at the same level as men, but were outperformed by non-transfer women (Sullivan et al., 2012).

In a series of qualitative studies, Brawner, Mobley, and Shealy, interviewed engineering transfer students at MIDFIELD institutions. In one of these qualitative studies, Mobley, Shealy, and Brawner (2012) focused on reasons students began their studies at another institution and their subsequent experiences with the application and admission process at the MIDFIELD institution. They found that students primarily began their studies at a different institution for several reasons including: (1) participation in a dual-degree program with a MIDFIELD institution, (2) scholarship restrictions, (3) financial advantages, and (4) students were initially denied admission to the MIDFIELD institution. In terms of the application and admission process, some of the institutions had formal transfer agreements, making the transfer process smooth for students; on the other hand, at institutions with no formal agreements, students received little assistance. Once students transferred to the MIDFIELD institution, most described experiencing “academic culture shock,” feeling overwhelmed by the difficulty of the courses and the professors’ expectations. To overcome this, students reported joining study groups to help with the academic side of transferring; students also reported joining social organizations and finding employment on campus as a way to fit in with the student culture at the new institution (Mobley, Shealy, & Brawner, 2012).

In a second qualitative study with students at four MIDFIELD institutions, Mobley and Brawner (2013) explored how engineering students obtained knowledge about transferring, specifically through orientation and academic advising. Results of 38 interviews indicated that personal motivation and resourcefulness, such as online research, were more important in learning about the transfer process than formal orientations and advising for this group of students. However, the most successful transfer experiences occurred through a combination of personal motivation and formal institutional programs (Mobley & Brawner, 2013). Mobley, Shealy, and Brawner (2013) continued their qualitative research on engineering transfer students, interviewing 18 first-generation students at two institutions. Their results suggest using a nuanced categorization of parental education when studying engineering transfer students. In their study, they used three categories for parental education: (1) low parental education, meaning both parents' highest level of education was high school or lower, (2) mid-level parental education, meaning both parents graduated high school and one or both attended college and/or received an associate's degrees, and (3) high parental education, meaning both parents earned a bachelor's degree or higher. They found that the mid-level category was important as it captured the experience of students' whose parents also attended a two-year college.

Zhang and Ozuna (2015) interviewed 21 engineering students at a four-year university who transferred from a community college; the primary focus of their study was the students' experiences in community college prior to transferring. Findings indicated that faculty at community college were the most important factor in supporting students' academic and interpersonal validation. Many participants were first-generation college students and had limited knowledge of the range of engineering fields they might pursue. In addition, family, especially parents, were an important support for students while attending community college. Students also felt that they benefitted from the learning environment in community college and that they were prepared for subsequent engineering coursework at a four-year university. Given the lower cost of attendance at community colleges, students reported that attending community college allowed them to explore various majors before committing to engineering (Zhang & Ozuna, 2015).

Background Characteristics of Engineering Students

As supported by Terenzini and Reason's (2005) conceptual framework described earlier, students' personal and academic background characteristics with which they enter college influence several student learning outcomes while in college. In engineering specifically, a number of demographic characteristics, such as gender and race/ethnicty (e.g. Murphy, Steele, &

Gross, 2007; Zastavker, Ong, & Page, 2006), as well as academic preparation variables, such as high school grade point average (GPA) and standardized test scores (e.g. French, Immekus, & Oakes, 2005; Zhang, Anderson, Ohland, & Thorndyke, 2004) influence students' decisions to major in engineering and their subsequent success in the major. In this dissertation, these demographic and pre-college academic characteristics were controlled for in the statistical modeling in order to determine if perceptions of climate are independently associated with academic outcomes.

Demographic Factors

As described throughout the literature review, gender and race are important predictors when studying the field of engineering. In their reports, Hall and Sandler (1982 and 1984) described a "chilly climate" for women and minority students in engineering classrooms that may have influenced their success and decision to remain in the major. Steele and his colleagues' studies on stereotype threat indicated that women and minority students in engineering might underperform due to the stereotypes of these groups in STEM fields (Murphy et al., 2007; Steele, 1997; Steele & Aronson, 1995). Furthermore, several studies indicate that females report feeling less competent and having lower ability perceptions than male students in engineering (Wilkins, 2004; Zastavker et al., 2006). While they did not find any gender differences, Marra, Rodgers, Shen, and Bogue (2012) did find that lack of belonging in engineering significantly contributed to minority students' decisions to leave engineering.

While gender and race are both important characteristics influencing students' experiences in college, researchers acknowledge that treating gender and race as unique experiences (i.e. all women grouped together, regardless of race) can be problematic, as noted in intersectionality research (e.g. Riley, Slaton, & Pawley, 2014). By doing this, researchers report only the main effects of gender and race, and may incorrectly interpret that “women of color have the problems of white women simply ‘added’ to the problems of men of color” (Riley et al., 2014). In this dissertation, the issue was tempered somewhat by including interaction variables for gender and race.

In addition to gender and race, parental education level is an important factor associated with a student’s success in engineering. Students who are the first in their families to attend college, or first-generation students, are less likely to enroll in college or earn a bachelor’s degree in any field (Chen, 2005; Ishitani, 2006) due to factors such as having less basic knowledge about postsecondary education, lower levels of family income and support, and inadequate secondary school preparation (Terenzini, Springer, Yaeger, Pascarella, & Nora, 1996; Warburton, Bugarin, Nunez, 2001). In the fields of science, mathematics, and engineering, students whose parents have earned a bachelor’s degree are more likely than first-generation students to choose these majors (Chen, 2005).

Pascarella, Wolniak, Pierson, and Terenzini (2003) examined the experiences of first-generation students attending community college and found that the largest differences were between first-generation students and students whose parents both had a bachelor’s degree or higher; students whose parents had a moderate level of postsecondary education did not differ significantly from first-generation students in terms of academic and non-academic experiences. The researchers also found that, by the end of the second year of community college, first-generation students demonstrated significant net outcomes advantages, indicating that in this setting, first-generation students may be sufficiently resilient (Pascarella et al., 2003).

As mentioned earlier, Mobley et al.’s (2013) research on engineering transfer students suggested using a nuanced categorization of parental education when studying engineering transfer students. The three categories they recommend were followed in this dissertation: (1) low parental education, meaning both parents' highest level of education was high school or lower, (2) mid-level parental education, meaning both parents graduated high school and one or both attended college and/or received an associate's degrees, and (3) high parental education, meaning both parents earned a bachelor's degree or higher.

Pre-College Factors

A student's academic preparation before college may also impact their academic outcomes while in college (Astin, 1993; Terenzini & Reason, 2005). Analyzing a database of all engineering students in nine college and universities from 1987 to 2002 (for a total of 87,167 students), Zhang et al. (2004) examined factors that influenced graduation rates. They found that high school GPA and mathematics SAT scores were positively correlated with graduation rates across all nine institutions; they also found that gender and ethnicity had significant impacts on graduation rates, but the directions of the associations were inconsistent across the institutions (Zhang et al., 2004). Using data from two cohorts of engineering students at one university, French et al. (2005) explored variables that influenced students' decisions to enroll in engineering and students' GPAs once enrolled in engineering. High school rank and SAT scores were significant predictors of both students' decisions to enroll in engineering and GPA; additionally, gender was a significant predictor of GPA, with female students having higher GPAs (French et al., 2005).

College Factors

As described in Terenzini and Reason's (2005) conceptual framework, the organizational context and environment may affect a student's experience at that institution. In this dissertation, several institutional factors were included for statistical control. At the individual level, the student's engineering discipline was included. In certain disciplines of engineering, the ratio of men to women is lopsided; for example, only 12.0% of computer engineering degrees and 13.5% of mechanical engineering degrees are conferred to women (Yoder, 2014). On the other hand, some disciplines, such as environmental engineering with 48.0% women and biomedical engineering with 40.6% women, are more balanced (Yoder, 2014). Because the interest in this dissertation was on classroom climate, the variation in gender ratios may influence students' perceptions of the climate. At the institution level, several factors were also added for statistical control, including the size (small, medium, or large), type of institution (public or private), the highest degree offered (bachelor's, master's, or research), as suggested by previous research (Lattuca, Terenzini, & Volkwein, 2006; Ro, Terenzini, & Yin, 2013).

In order to compare the results from the community college students to the four-year university students found in this study, the highest level in hierarchical linear modeling (HLM) was the institution, i.e. either the community college or the university. However, previous research with university engineering students suggests that differences in student outcomes may be attributed more to the engineering program (e.g. mechanical, environmental, etc.), rather than the engineering department as a whole at the university (Knight et al., 2012; Lattuca, Terenzini, Harper, & Yin, 2010). Therefore, after conducting the HLM analysis for university students with the institution at the highest level, another analysis was conducted with the program (e.g. mechanical engineering at a certain university) at the highest level to explore possible differences.

Chapter Summary

Chapter 2 of this dissertation began with a description of the conceptual framework that supported the current study. The conceptual framework was informed primarily by two frameworks: (1) Steele and Aronson's (1995) concept of stereotype threat and (2) Terenzini and Reason's (2005) conceptual framework for studying student learning and persistence in college. The main focus of this dissertation was the relationship between classroom climate and fundamental skills related to engineering; as such, Steele and Aronson's work on stereotype threat supported the exploration of this relationship. Methodologically, Terenzini and Reason's (2005) conceptual framework supported the need for control variables in the statistical models that were used.

Following the description of the conceptual framework, Chapter 2 continued with a review of the relevant literature organized around three main topic areas: (1) Classroom Climate in Higher Education, (2) Community College Pre-Engineering Students, and (3) Background Characteristics of Engineering Students. In 1982, Hall and Sandler published a report on college classrooms, indicating that women and minorities in higher education may experience a chilly climate. Since this report, many studies have focused on this topic and have supported the chilly climate idea to varying degrees (e.g. Janz & Pyke, 2000; Morris & Daniel, 2008; Serex & Townsend, 1999). In engineering specifically, classrooms are often characterized as male-normed, making engineering classrooms potentially chillier for women (Morris & Daniel, 2008; Vogt et al., 2007). The climate students experience both inside and outside of the classroom may affect their decisions to persist in to a degree (Pascarella & Terenzini, 2005; Seymour & Hewitt, 1997).

This study builds on the previous research by focusing specifically on engineering classrooms in both community colleges and four-year universities. While research on classroom climate has been conducted at the four-year level, there is some inconsistency in findings. In this study, university students' perceptions of classroom climate in engineering were explored; these results also served as a basis for comparison for the community college students. Research on community college engineering classrooms, on the other hand, is scarce, again supporting the need for this study (Laanan, Jackson, & Darrow, 2010; Ogilvie, 2014).

Chapter 3: Methodology

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering. The study was guided by the following research questions:

1a. What are community college engineering students' perceptions of their classroom climate and fundamental engineering skills?

1b. What are university engineering students' perceptions of their classroom climate and fundamental engineering skills?

1c. How do community college engineering students' perceptions of their classroom climate and fundamental engineering skills compare to and/or differ from university engineering students' perceptions?

2a. How are community college engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

2b. How are university engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

In this chapter, the process of data collection and survey instrument development, which took place as part of another study—*Prototype to Production: Processes and Conditions for Preparing the Engineer of 2020* (P2P)—is described. The sampling, weighting, and imputation of the data as well as descriptive statistics for the sample are also included. Following this, the proposed analyses used to address each research question, including exploratory factor analysis (EFA), linear equating, and hierarchical linear modeling (HLM), are supported.

Data

For this study, data from a National Science Foundation sponsored project, *Prototype to Production: Processes and Conditions for Preparing the Engineer of 2020* (P2P) were examined. These data were collected in 2009 from a nationally representative sample of engineering undergraduates, alumni, faculty, program chairs, and associate deans from 31 four-year colleges and universities and from 15 pre-engineering community college programs. The institutions included in the study are listed in Table 1. The purpose of the original P2P study was to examine the curricular and co-curricular experiences of engineering students in order to understand if students were gaining the knowledge and skills needed for success in the workforce, as identified by the National Academy of Engineering. In the current study, survey data from engineering undergraduates at four-year institutions and from pre-engineering students at community colleges were analyzed.

Survey Instrument Development

Survey instruments used to collect data were developed by a team of engineering and education researchers through a comprehensive two-year process. Over the course of a year, the team carried out an extensive literature review on several engineering outcomes, including fundamental skills, design skills, interdisciplinary skills, communication skills, team-work skills, leadership skills, and cultural competence. Based on the literature and a review of existing survey instruments, the team developed a set of potential survey items. During this time, the research team also conducted focus groups and interviews with students, faculty, administrators, and alumni at five college and universities, including two community colleges, in order to further explore these engineering outcomes and support instrument development.

Table 1. *Institutions Included in the Dataset*

Research Institutions	**Baccalaureate Institutions**
Arizona State University (Main & Polytechnic)	Harvey Mudd College (CA)
Brigham Young University (UT)	Lafayette College (PA)
Case Western Reserve University (OH)	Milwaukee School of Engineering (WI)
Colorado School of Mines	Ohio Northern University
Dartmouth College (NH)	Penn State Erie, The Behrend College
Johns Hopkins University (MD)	West Virginia University Institute of Technology
Massachusetts Institute of Technology	**Community Colleges**
Morgan State University (MD)	Anne Arundel Community College (MD)
New Jersey Institute of Technology	Austin Community College (TX)
North Carolina A&T	Borough of Manhattan Community College (NY)
Purdue University (IN)	Brookdale Community College (NJ)
Stony Brook University (NY)	Community College of Baltimore County (MD)
University of Illinois at Urbana-Champaign	Miami Dade College (FL)
University of Michigan	Monroe Community College (NY)
University of New Mexico	Montgomery College (MD)
University of Texas, El Paso	Prince George Community College (MD)
University of Toledo (OH)	Richland College (TX)
Virginia Tech	Santa Fe College (FL)
Master's/Special Institutions	South Texas College (TX)
California Polytechnic State University	Union Community College (NJ)
California State University, Long Beach	Valencia Community College (FL)
Manhattan College (NY)	Wake Technical Community College (NC)
Mercer University (GA)	
Rose-Hulman Institute of Technology (IN)	
University of South Alabama	

The second year of instrument development was allocated to drafting survey items for review by engineering faculty at the Pennsylvania State University. Following this review, the survey items were pilot tested with engineering undergraduates at Penn State's University Park and Altoona campuses. The results were analyzed through factor analysis techniques and the instruments were revised accordingly. The research team then met with the engineering faculty at Penn State again to make final revisions to the survey instruments before administering them to the full P2P sample.

Sample, Weighting, and Imputation

In order to obtain a sampling frame, the P2P research team referred to the American Society for Engineering Education's institutional database for the 2007-2008 school year. The P2P team employed a cross-sectional, 6 x 3 x 2 disproportionate, stratified, random sampling technique in order to select a nationally representative sample of four-year institutions. The strata included were: six engineering disciplines (biomedical/bioengineering, chemical, civil, electrical, industrial, and mechanical), three levels of highest degree offered (bachelor's, master's, and doctoral), and two levels of institutional control (public and private). Using this design, Penn State's Survey Research Center randomly selected 23 four-year institutions. The other four-year institutions in the sample were "pre-seeded" from a partner qualitative study, *Prototyping the Engineer of 2020: A 360-degree Study of Effective Education* (P360).

The 15 community colleges included in the sample were nonrandom. Due to the small size and number of pre-engineering community college programs, selecting a random sample of community colleges may not have generated a large enough sample for analysis. Instead, the P2P research team, along with key informants at community colleges, identified 20 community colleges with large pre-engineering enrollments; of these community colleges, 15 agreed to participate in the study. Students who indicated their intention to transfer to a four-year engineering program were invited to participate in the study. Because of this nonrandom sampling, the generalizability of the results for the current study were limited.

Penn State's Survey Research Center collected the data through a web-based questionnaire for the four-year students and a paper-based questionnaire for the two-year students. Of the 32,737 four-year student surveys sent, 5,249 responded for a response rate of 16%; of the 8,261 two-year student surveys sent, 1,245 responded for a response rate of 15%. In order to account for differences due to response bias in both the four-year and two-year student surveys, cases were weighted based on gender, race/ethnicity, class year, and discipline within engineering; adjustments were also made to account for differences in institutional response rates. Missing data were imputed for both samples in order to retain the maximum number of cases. Imputation procedures followed those recommended by Dempster, Laird, and Rubin (1977) and Graham (2009) using the Expectation-Maximization (EM) algorithm in SPPS v.18 (as cited in the P2P study).

Table 2 provides the weighted demographic information for the sample of community college and the four-year college students in this study. In terms of gender, both samples have more men than women—86% of the community colleges students were men and 81% of the four-year college students were men. For the community college sample, Caucasian students were the largest racial/ethnic group (36%), followed by Hispanic students (23%), and African American students (16%). For the four-year college sample, 51% of the students were Caucasian, followed by 20% in the 'Other' category, and 13% Asian American. In this dissertation, the 'Other' category was created to simplify analyses and was made up of students who identified as either Native American, Foreign national (i.e., citizen of another country), Naturalized U.S. citizen, as well as those who originally chose 'Other.'

When asked what field they would most likely earn their bachelor's degree in, the most popular engineering disciplines for community college students were mechanical (25%), electrical (23%), and other (19%).When asked to report their current major, the most popular engineering disciplines for the four-year sample were mechanical (33%), electrical (18%), and civil (17%). Almost 70% of the four-year sample reported that their parent's highest education level was a bachelor's degree or higher compared to about 35% of the community college sample. Only 10% of the four-year students reported that their parent's highest education level was a high school diploma or below compared to 32% of the community college sample.

For high school GPA, 74% of the four-year students reported having GPAs of 3.5 or above in high school compared to 28% of the community college students; both the four-year and community college samples had similarly low numbers of students in the bottom two GPA categories, which indicate GPAs below 1.99 (0% for university students and 3% for community college students). The average age for community college students was slightly higher than for four-year college students (24.5 and 22.0 years respectively). The average SAT composite score for four-year students was 1861.2 (*SD* = 251.1). Because relatively few community college students in the sample completed the SATs, these scores were not included in this study.

Table 2. *Demographic Information for the Sample*

	Community College		**Four-year College**	
	Frequency	Percent	Frequency	Percent
Gender				
Men	1,119	86%	4,350	81%
Women	187	14%	1,056	20%
Race/Ethnicity				
African American	213	16%	232	4%
Asian American	86	7%	703	13%
Caucasian	463	36%	2,775	51%
Hispanic	298	23%	598	11%
Other	245	19%	1,098	20%
Discipline[1]				
Bio/Biomedical	34	3%	335	6%
Chemical	70	5%	547	10%
Civil	201	15%	932	17%
Electrical	298	23%	979	18%
Industrial	32	3%	252	5%
Mechanical	320	25%	1,795	33%
General	15	1%	342	6%
Other	246	19%	218	4%
Undeclared	90	7%	6	0%
Parent Education Level				
High School or below	415	32%	537	10%
Some College or Associate's	438	34%	1,108	21%
Bachelor's or higher	452	35%	3,761	70%
High School GPA				
1.49 or below (below C-)	12	1%	19	0%
1.50 - 1.99 (C- to C)	29	2%	25	0%
2.00 - 2.49 (C to B-)	152	12%	88	2%
2.50 - 2.99 (B- to B)	272	21%	247	5%
3.00 - 3.49 (B to A-)	448	35%	960	18%
3.50 or above (A- to A)	358	28%	3892	74%
	Mean	**S.D.**	**Mean**	**S.D.**
Age	24.5	7.1	22.0	3.6
SAT Composite Score[2]	-	-	1861.2	251.1
Total	1,306		5,406	

Note. All data weighted and imputed. 1 indicates that community college students were asked what their *intended* major would be once transferring; four-year students were asked about their *current* major. 2 indicates that because relatively few community college students in the sample completed the SATs, they are not included here.

Analysis

In this section, the analysis used to answer each research questions is described. For clarity, Table 3 lists each research question and the corresponding methodology and data chosen for that question.

Table 3. *Research Questions, Analysis, and Data*

Research Question	Analysis	Data
1a. What are community college engineering students' perceptions of their classroom climate and fundamental engineering skills?	Exploratory Factor Analysis (EFA), Descriptive statistics	Community college data
1b. What are university engineering students' perceptions of their classroom climate and fundamental engineering skills?	Exploratory Factor Analysis (EFA), Descriptive statistics	Four-year university data
1c. How do community college engineering students' perceptions of their classroom climate and fundamental engineering skills compare to and/or differ from university engineering students' perceptions?	Linear equating, Descriptive comparison of the results from research questions 1a. and 1b.	Both community college and four-year university data
2a. How are community college engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate? i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity? ii. Do these perceptions vary by institution?	Hierarchical Linear Modeling (HLM)	Community college data
2b. How are university engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate? i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity? ii. Do these perceptions vary by institution?	Hierarchical Linear Modeling (HLM)	Four-year university data

Exploratory Factor Analysis

An exploratory factor analysis (EFA) was conducted on the survey instruments in order to establish measures of classroom climate and fundamental skills in engineering. EFA is a statistical technique that is used to explore the dimensionality of an instrument by finding a smaller number of interpretable factors needed to explain the underlying relationships among variables (Brown, 2006; Rencher, 2002). In this study, an EFA was conducted on both the community college survey and the four-year college survey to determine the latent constructs measured and to determine the surveys' qualities as measurement instruments. The resulting constructs were then used in the HLM analysis.

In this dissertation, a total of four EFAs were conducted with the data, two for each dataset. The survey instruments were first grouped by the content of the items, i.e. items that related to the individual students' skills, classroom, or program, in order to conduct separate EFAs on each. The interest in this study was on the student and classroom levels, and thus two EFAs were conducted per dataset. All EFA analyses in this study were conducted using Mplus Version 7 (Muthén & Muthén, 2012) under maximum likelihood estimation and an oblique promax rotation. A preliminary inspection of the bivariate correlation matrix for all of the items showed many correlations above 0.3, indicating that a factor analysis was appropriate for this data.

To determine the number of factors on each survey instrument, several criteria, including the scree plot, fit statistics, factor loadings, and substantive interpretability, were examined. A scree plot is a graphical representation of the eigenvalues and is used to visually assess how many factors explain most of the variability of the data; the point at which the slope appears to level off, or the "elbow" of the graph, indicates the number of factors. The fit statistics of EFA include the Chi-square criterion, the root mean square error approximation (RMSEA), and the root mean square residual (RMR). The Chi-square criterion suggests that the p-value should be above 0.05; however, given that this criterion is highly affected by sample size, other fit indices are generally needed to determine the number of factors (Rencher, 2002). For the root mean square error approximation (RMSEA), a value of less than 0.05 indicates a good fit and values between 0.05 and 0.08 indicate moderate fit (Browne & Cudeck, 1992). For the root mean square residual (RMR), a value of less than 0.08 indicates good fit (Browne & Cudeck, 1992). After examining the Scree plot and fit statistics, it is important to consider the factor loadings as well as the substantive interpretability of these factors. In this study, factor loadings above 0.32 were considered as the minimum loading for an item (Costello & Osborne, 2005).

Equating

While the items on the community college and university student survey were nearly the same, some of the wording of the items and the stems were not exactly the same. For example, on the community college survey, one item reads: "Please rate your ability to apply computer tools and applications to *real-world* problems." On the university survey, a similar item reads: "Please rate your ability to apply computer tools and applications to *engineering* problems." Thus, in order to compare the results from the two surveys, it was necessary to first linearly equate the scores. Equating is, "a statistical process that is used to adjust scores on test forms so that scores on the forms can be used interchangeably" (Kolen & Brennan, 2014).

There are several commonly used equating designs, such as random groups, single group with counterbalancing, and common-item nonequivalent groups design (Kolen & Brennan, 2014). For this study, the common-item nonequivalent groups design was used because two groups of students from different populations (i.e. the community college or the university) were each administered different forms of the survey, which included a common set of items. The common set of items were those that were worded exactly the same on each survey. Linear equating analysis in this dissertation was conducted using the Common Item Program for Equating (CIPE) version 2.0 (Kolen, 2004). The equated scores allowed for comparisons between the community college and university students.

Descriptive Analyses

After conducting EFAs on both surveys and equating the results, the scores from two factors—Classroom Climate and Fundamental Engineering Skills—were compared descriptively for the community college and university students. To answer research question 1c, all results for questions 1a and 1b from the community college students and university students were compared descriptively, focusing on similarities and differences between the two groups of students. The mean and standard deviation scores of perceptions of Classroom Climate and Fundamental Engineering Skills from questions 1a and 1b were compared for both groups.

Hierarchical Linear Modeling

Hierarchical linear modeling (HLM), sometimes referred to as multilevel modeling, is a popular statistical technique in the social sciences that allows for researchers to examine variation at multiple levels (e.g. a student within a school) or across multiple time points (e.g. reading test scores of a student at various points of elementary school). HLM has an advantage over other statically techniques, such as ordinary least squares (OLS) regression, in that it permits researchers to appropriately deal with hierarchical or nested data structures (Osborne & Neupert, 2013; Raudenbush & Bryk, 2002; Snijders & Bosker, 1999). For example, students in the same classroom are exposed to the same environment—the same teacher, other students, the number of books in the classroom, etc.—and therefore their responses on a particular test are likely more similar to each other than to students at a different school, who are exposed to a different environment. The observations from these individual students are not fully independent of each other, violating an assumption of many statistical techniques, including OLS regression. Another advantage of HLM is that it allows researchers to handle cross-level data. For example, if researchers are interested in the effect of a certain teaching style on student achievement, they could aggregate this information and assign the same teaching characteristics to all students. Again, this violates the assumption of independence of observation. Using HLM, on the other hand, researchers may place variables, such as teaching style, at the appropriate level (Osborne & Neupert, 2013; Raudenbush & Bryk, 2002; Snijders & Bosker, 1999).

In HLM analysis, the individual level, (or lowest level of data) i.e. level-1, analysis is similar to regression in that the dependent variable is predicted as a function of a linear combination of one or more level-1 independent variables and an intercept, as shown:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_1 + \ldots + \beta_{kj}X_k + r_{ij}$$

where β_{0j} represents the intercept of the dependent variable in group *j*, β_{1j} represents the slope of independent variable X_1 of group *j*, and r_{ij} represents the residual of individual *i* in group *j*. At level-2, the level-1 slopes and intercepts become the dependent variables that are predicted by level-2 independent variables, as shown:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}W_1 + \ldots + \gamma_{0k}W_k + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

where the slopes, represented by γ_{00} and γ_{10}, and intercepts, represented by γ_{01} and γ_{0k}, predict β_{0j} and β_{1j} from the level-2 variable of W_1.

In this dissertation, a two-level HLM was chosen to address research questions 2a and 2b. The level-1 unit of analysis was the individual student and the level-2 unit was either the community college or the four-year university. All HLM analyses in this study were conducted using HLM 7 software (Raudenbush, Bryk, & Congdon, 2011) with full maximum likelihood estimation. Like regression, HLM has several assumptions, including a linear relationship between variables, normality of errors, homogeneity of variance, and independence of observations (Raudenbush & Bryk, 2002), which were checked after fitting a final model.

Student Level Variables

The dependent variable in this study was fundamental skills in engineering, a construct determined by the EFA results in the previous research questions. The student-level control covariates for both the community college and four-year models were gender, race/ethnicity, the interactions of gender by race/ethnicity, age, and parent education level (classified as either high, mid, or low); for the community college models, high school grade point average (GPA) was included, while in the four-year college models, Scholastic Aptitude Test (SAT) scores were included.

Institution Level Variables

The primary independent variable of interest in this study was classroom climate, a construct also determined by the EFA results; because students were asked about their classroom experience in general at their institution, not for a specific course, this variable was included at level two. For both the community college analysis and the four-year student analysis, level two was the institution. For the four-year analysis, institution size (classified as small, medium, or large), highest degree offered (bachelor's, master's, or research), and institution type (public or private) were included as control variables.

Model Building

For the HLM analysis, the first step in model building was to formulate the fully unconditional model, or null model. An unconditional model is used to calculate the intraclass correlation coefficient (ICC), or the proportion of variance in the outcome variable that is between groups; as such, the ICC provides support for the use of multilevel modeling (Raudenbush & Bryk, 2002). The unconditional model also provides several baseline coefficients and statistics, such as the deviance statistic, which are used for comparison in subsequent models (Raudenbush & Bryk, 2002). Shown below are the fully unconditional models used in this analysis.

Level 1:

$$FundamentalSkills_{ij} = \beta_{0j} + r_{ij}, \text{ where } r_{ij} \sim i.i.d.\, N(0, \sigma^2),$$

where $FundamentalSkills_{ij}$ represents the self-reported fundamental engineering skills of student *i* in institution *j*; β_{0j} represents the institution mean of fundamental engineering skills of institution *j*; and r_{ij} represents the random error of student *i* in institution *j* which is assumed to be independent and identically distributed with a mean of 0 and variance of σ^2.

Level 2:

$$\beta_{oj} = \gamma_{00} + u_{oj},$$

where γ_{00} represents the group mean fundamental engineering skills of all institutions; u_{0j} represents the random error.

After the unconditional model, a series of models were built with various combinations of level-1 and level-2 variables added, the results of which were compared to the original baseline model. This process is described in more detail in Chapter 4 of this dissertation. The final model for both the community college data and the university student data included all of the level-1 and level-2 variables of interest.

As discussed in the literature review, one consideration in model building was centering of the variables, which can either be around the grand mean or group mean. Centering is a simple transformation of a variable that can simplify the interpretation of the intercept or make the interpretation more substantively meaningful. In this study, group mean centering was used in order to determine the effects of between- and within- group differences in climate on student perceptions of abilities. Many variables, however, were dummy coded; for example, gender was coded 0 to indicate female and 1 to indicate male. For dummy coded variables, centering was not necessary as it would complicate the interpretation of the intercepts.

Chapter Summary

In this chapter, the datasets used in this study were described, including the sampling, weighting, and imputation techniques. The survey instrument development process that occurred as part of the original P2P study was also described. Descriptive statistics for the students in the both the community college and university student sample were provided. In addition, the methodology used to answer each research question was defined.

Research questions 1a and 1b were addressed by conducting an EFA on each of the two surveys in order to determine constructs for classroom climate and fundamental skills in engineering. In order to compare the results of the EFA analysis, and to address research question 1c, linear equating was necessary as the items on the two surveys were not identically worded. Lastly, to answer research questions 2a and 2b, HLM analyses were conducted on both sets of data. The use of HLM was justified by the nested data structure of students within institutions.

Chapter 4: Results

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering. The study was guided by the following research questions:

1a. What are community college engineering students' perceptions of their classroom climate and fundamental engineering skills?

1b. What are university engineering students' perceptions of their classroom climate and fundamental engineering skills?

1c. How do community college engineering students' perceptions of their classroom climate and fundamental engineering skills compare to and/or differ from university engineering students' perceptions?

2a. How are community college engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

2b. How are university engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

   i. Do these perceptions vary by the individual characteristics of gender or race/ethnicity?

   ii. Do these perceptions vary by institution?

Chapter 4 is organized around the results of these research questions. This chapter includes the results of the following analyses required to answer these questions: exploratory factor analysis (EFA), linear equating, descriptive analysis, and hierarchical linear modeling (HLM).

1a. What are community college engineering students' perceptions of their classroom climate and fundamental engineering skills?

Community College EFA Results

In order to establish measures of classroom climate and fundamental skills in engineering, an exploratory factor analysis (EFA) was conducted on both the community college and university student surveys. All EFA analyses in this study were conducted using Mplus Version 7 (Muthén & Muthén, 2012) under maximum likelihood estimation and an oblique promax rotation. A preliminary inspection of the bivariate correlation matrix for all of the items showed many correlations above 0.3, indicating that a factor analysis was appropriate for this data. In order to determine the number of factors on each survey instrument, several criteria, including the scree plot, fit statistics, and substantive interpretability, were examined.

For the community college instrument, the survey items were grouped by the content of the items, i.e. items that related to the individual students' skills, classroom, or program, in order to conduct separate EFAs on each; the interest in this study was on the student and classroom levels, and thus two EFAs were conducted. For the items related to individual student skills, 20 attitudinal items were included. All items were on a five-point Likert scale from "Weak/none," "Fair," "Good," "Very Good," to "Excellent." The scree plot, which is a graphical representation of the eigenvalues, was used to visually assess how many factors explain most of the variability of the data; the point at which the slope appears to level off, or the "elbow," indicates the number of factors. For this EFA, the scree plot (shown in Figure 2) indicated that either a four-, five-, or six-factor model was possible.

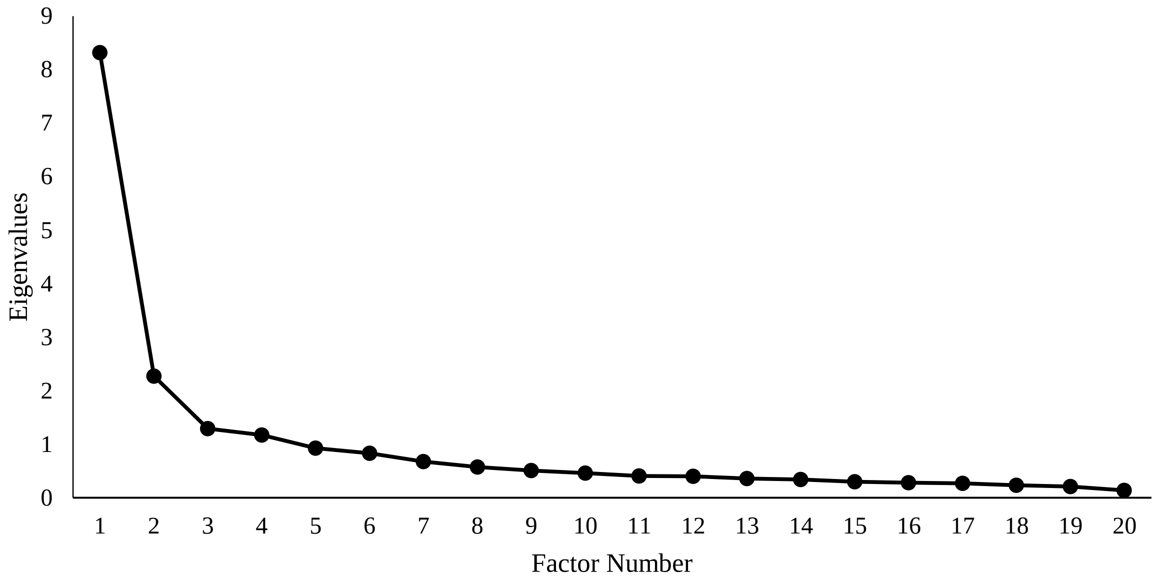

Figure 2. Scree plot for the community college survey: individual skills.

In continuing to determine the number of factors, the fit statistics (shown in Table 4) were inspected next. The Chi-square criterion suggests that the p-value should be above 0.05, which was not met in any model. Given that this criterion is highly affected by sample size (Rencher, 2002), other indices were examined. For the root mean square error approximation (RMSEA), a value of less than 0.05 indicates a good fit and values between 0.05 and 0.08 indicate moderate fit (Browne & Cudeck, 1992). In this case, both the five- and six-factor model indicated moderate fit (RMSEA = 0.068 and 0.055, respectively). For the root mean square residual (RMR), a value of less than 0.08 indicates good fit (Browne & Cudeck, 1992), which all of the models met.

Table 4. *Fit Statistics for the Community College Survey: Individual Skills*

No. of Factors	Chi-Square X^2	d.f.	p-value	RMSEA	RMR	Negative Residual Variance
Results for Initial EFA (20 Items)						
2	3257.41	151	0.000	0.129	0.070	No
3	2000.91	133	0.000	0.106	0.058	No
4	1275.51	116	0.000	0.090	0.042	No
5	673.47	100	0.000	0.068	0.026	No
6	406.38	85	0.000	0.055	0.018	No
Results of Final EFA (19 Items)						
5	462.03	86	0.000	0.059	0.021	No

Note. n = 1,245.

Based on the scree plot and the fit indices, the five- and six-factor models looked the most plausible; therefore, the factor loadings for both were examined. Factor loadings above 0.32 were considered as the minimum loading for an item (Costello & Osborne, 2005). In looking at the substantive interpretability of the salient factor loadings, a five-factor model was supported. One cross-loaded item was eliminated and another EFA was conducted on the remaining 19 items. A five-factor model was again supported by the scree plot, fit statistics (RMSEA = 0.059; RMR = 0.021), and substantive interpretability of the loadings. The final five factors for this portion of the community college survey, along with the items that loaded on each factor and the factor loadings, are presented in Table 5. In order to support the reliability of these factors, Cronbach's alpha was computed for each; as shown in Table 5, all factors have high reliability with Cronbach's alphas at or above 0.8 (Cronbach, 1951). In this dissertation, the factor "Fundamental Engineering Skills" was used in further analyses.

Table 5. *Factors for the Community College Survey: Individual Skills*

Factor and Items	**Factor Loadings**	**Cronbach's Alpha, α**
Factor 1: Fundamental Engineering Skills		0.80
Please rate your ability to apply:		
Math to real-world problems.	0.652	
The physical sciences to real-world problems.	0.891	
Computer tools and applications to real-world problems.	0.414	
Life sciences to real-world problems.	0.555	
Factor 2: Contextual Awareness		0.85
Please rate your:		
Knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to a problem.	0.736	
Knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit.	0.577	
Ability to use what you know about different cultures, social values, or political systems in developing problem solutions.	0.910	
Ability to recognize how different contexts can change a problem solution.	0.707	
Factor 3: Communication		0.81
Please rate your ability to:		
Write a well-organized, coherent report.	0.659	
Make effective audiovisual presentations.	0.826	
Construct tables or graphs to communicate a solution.	0.785	
Make myself understood in conversations with others.	0.477	
Factor 4: Teamwork		0.93
Please rate your ability to:		
Work with others to accomplish group goals.	0.857	
Work in teams of people with a variety of skills and backgrounds.	0.980	
Work in teams where knowledge and ideas from multiple fields must be applied.	0.717	
Factor 5: Leadership (α = 0.90**)**		0.90
Please rate your ability to:		
Help your group or organization work through periods when ideas are too many or too few.	0.789	
Develop a plan to accomplish a group or organization's goals.	0.818	
Take responsibility for group or organizational performance.	0.858	
Motivate people to do the work that needs to be done.	0.643	

Note. All items were on a five-point Likert scale with 1 = Weak/none, 2 = Fair, 3 = Good, 4 = Very Good, and 5 = Excellent; n = 1,245.

Next, an EFA was conducted on the items related to classroom experiences on the community college survey. Twelve attitudinal items on a five-point Likert scale were included in this analysis. Again the scree plot (shown in Figure 3), fit statistics (shown in Table 6), and substantive interpretability of the factor loadings were examined to determine the number of factors.

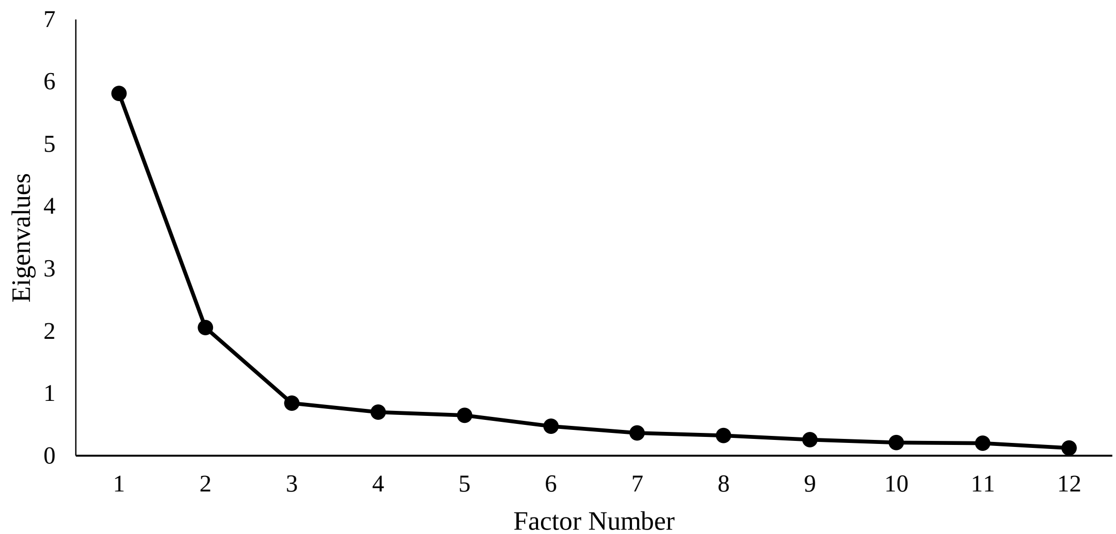

Figure 3. Scree plot for the community college survey: classroom experiences.

Based on the scree plot, a two- or three-factor model was supported. However, after examining the fit statistics and substantively interpretability of the factors, a two-factor model was supported (RMSEA = 0.161; RMR = 0.056).

Table 6. *Fit Statistics for the Community College Survey: Classroom Experiences*

Results for Final EFA (12 Items)						
	Chi-Square					
No. of Factors	X^2	d.f.	p-value	RMSEA	RMR	Negative Residual Variance
1	3398.36	54	0.000	0.223	0.149	No
2	1437.30	43	0.000	0.161	0.056	No
3	736.34	33	0.000	0.131	0.048	No
4	252.14	24	0.000	0.087	0.022	No

Note. n = 1,245.

The two factors for this portion of the community college survey, along with the items that loaded on each factor, the factor loadings, and the Cronbach's alpha are presented in Table 7. Both factors had high reliability, with Cronbach's alphas above 0.8 (Cronbach, 1951). One factor, "Classroom Climate" was used in further analyses.

Table 7. *Factors for the Community College Survey: Classroom Experiences*

Factor and Items	Factor Loadings	Cronbach's Alpha, α
Factor 1: Classroom Climate[1]		0.92
In your courses, do:		
Some male students treat other male students better than female students.	0.740	
Some white students treat other white students better than non-white students.	0.871	
When working in groups, some male students treat other male students better than female students.	0.827	
When working in groups, some white students treat other white students better than non-white students.	0.877	
Some instructors treat male students better than female students.	0.754	
Some instructors treat white students better than non-white students.	0.767	
Women students get treated better than male students.	0.598	
Minority students get treated better than white students.	0.590	
Factor 2: Identity in Engineering Field[2]		0.86
Please indicate your level of agreement with each of the following statements:		
My gender has or will influence my choice of engineering field.	0.519	
My gender will negatively influence my engineering career.	0.747	
My race/ethnicity will negatively influence my choice of engineering field.	0.901	
My race/ethnicity will negatively influence my engineering career.	0.885	

Note. All items were on a five-point Likert scale, however, not all scales were identical; 1 indicates a Likert scale of: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Very often; 2 indicates a scale of: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree; n = 1,245.

Summary of Findings

Table 8 provides a summary of findings for the community college student survey, including the factor name, Cronbach's alpha, mean total score, as well as, the mean score for each factor. Community college engineering students' perceptions of their classroom climate yielded a mean score of 4.37 (*SD* = 0.71); these students' perceptions of their fundamental skills in engineering yielded a mean score of 3.60 (*SD* = 0.78).

Table 8. *Summary of the Community College Survey Factors*

Factor	α	Mean Total Score (s.d)	Mean Score (s.d.)
Fundamental Engineering Skills	0.80	14.41 (3.11)	3.60 (0.78)
Contextual Awareness	0.85	14.04 (3.19)	3.51 (0.80)
Communication	0.81	14.59 (3.16)	3.65 (0.79)
Teamwork	0.93	12.07 (2.47)	4.02 (0.82)
Leadership	0.90	15.27 (3.34)	3.82 (0.84)
Classroom Climate	0.92	34.96 (5.68)	4.37 (0.71)
Identity in Engineering Field	0.86	16.95 (3.49)	4.24 (0.87)

Note. n = 1,245.

1b. What are university engineering students' perceptions of their classroom climate and fundamental engineering skills?

University Student EFA Results

For the university student survey, additional EFAs, again using Mplus Version 7 (Muthén & Muthén, 2012) under maximum likelihood estimation and promax rotation, were conducted. As with the community college survey, the items on the university student survey were first grouped by the content of the items, i.e. items that related to the individual students' skills, classroom, or program. An EFA was conducted on two groupings—individual student skills and classroom experiences. For the individual student skills, 51 attitudinal items on a five-point Likert scale were included in the initial EFA. Although all items were on a five-point Likert scale, the scales were not the same for all as described in the notes portion of Table 10. After examining the factor loadings of the initial EFA, there were five items that did not load onto any factor and were therefore deleted; a second EFA was conducted on the remaining 46 items. The results of this analysis are shown in Figure 4 and Table 9.

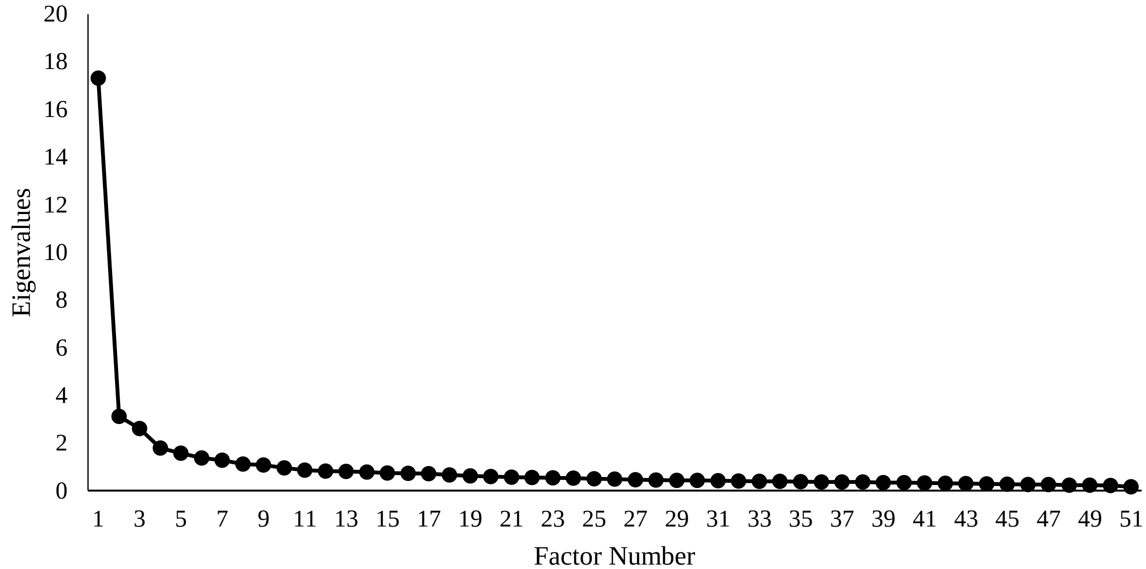

Figure 4. Scree plot for the university student survey: individual skills.

The scree plot, fit statistics, and substantively interpretability of the factor loadings supported an eight-factor model (RMSEA = 0.049; RMR = 0.021); the factor names, loadings, and corresponding items are shown in Table 10.

Table 9. *Fit Statistics for the University Survey: Individual Skills*

			Results of Initial EFA (51 Items)			
	Chi-Square					
No. of Factors	X^2	d.f.	p-value	RMSEA	RMR	Negative Residual Variance
2	43241.96	1174	0.000	0.083	0.067	No
3	32542.59	1125	0.000	0.073	0.047	No
4	25605.49	1077	0.000	0.066	0.039	No
5	21123.60	1030	0.000	0.061	0.034	No
6	16712.81	984	0.000	0.055	0.031	No
7	14069.93	939	0.000	0.052	0.028	No
8	11365.55	895	0.000	0.047	0.025	No
9	9186.66	852	0.000	0.043	0.020	No
			Results of Final EFA (46 Items)			
8	9290.58	695	0.000	0.049	0.021	No

Note. n = 5,249.

To support the reliability of these factors, Cronbach's alpha was computed for each. As shown in Table 10, most factors (six of eight) have high reliability with Cronbach's alphas above 0.8; the remaining two factors have acceptable reliability with Cronbach's alphas above 0.65 (Cronbach, 1951).

Table 10. *Factors for the University Survey: Individual Skills*

Factor and Items	**Factor Loadings**	**Cronbach's Alpha, α**
Factor 1: Fundamental Skills in Engineering[1]		0.73
Please rate your ability to apply:		
Math to engineering problems.	0.663	
The physical sciences to engineering problems.	0.597	
Computer tools and applications to engineering problems.	0.329	
Factor 2: Design Skills[1]		0.93
Please rate your ability to:		
Define design problems and objectives clearly and precisely.	0.680	
Ask questions to understand what a client/customer really wants in a "product."	0.695	
Undertake a search (literature review, databases, benchmarking, reverse-engineering, etc.) before beginning team-based brain-storming.	0.528	
Take into account the design contexts and the constraints they may impose on each possible solution (social, cultural, economic, environmental, political, ethical, etc.).	0.694	
Generate and prioritize criteria for evaluating the quality of a solution.	0.787	
Brainstorm possible engineering solutions.	0.678	
Apply systems thinking in developing solutions to an engineering problem.	0.684	
Develop pictorial representations of possible designs (sketches, renderings, engineering drawings, etc.).	0.610	
Evaluate design solutions based on a specified set of criteria.	0.851	
Producing a product (prototype, program, simulation, etc.).	0.779	
Break down a design project into manageable components or tasks.	0.579	
Recognize when changes to the original understanding of the problem may be necessary.	0.507	
Factor 3: Contextual Awareness[1]		0.91
Please rate your:		
Knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to an engineering problem.	0.772	

Knowledge of the connections between technological solutions and their implications for whom it benefits.	0.773	
Ability to use what you know about different cultures, social values, or political systems in engineering solutions.	0.799	
Ability to recognize how different contexts can change a solution.	0.631	
Factor 4: Communication[1]		0.86
Please rate your ability to:		
Write a well-organized, coherent report.	0.696	
Make effective audiovisual presentations.	0.718	
Construct tables or graphs to communicate a solution.	0.635	
Communicate effectively with clients, teammates, and supervisors.	0.671	
Communicate effectively with *non-technical* audiences.	0.620	
Communicate effectively with people from different cultures or countries.	0.363	
Factor 5: Teamwork[1]		0.85
Please rate your ability to:		
Work with others to accomplish group goals.	0.867	
Work in teams of people with a variety of skills and backgrounds.	0.959	
Work in teams where knowledge and ideas from multiple engineering fields must be applied.	0.492	
Work in teams that include people from fields *outside engineering*.	0.419	
Put aside differences within a design team to get the work done.	0.397	
Factor 6: Leadership[1]		0.90
Please rate your ability to:		
Help your group or organization work through periods when ideas are too any or too few.	0.778	
Develop a plan to accomplish a group or organization's goals.	0.816	
Take responsibility for group's or organization's performance.	0.814	
Motivate people to do the work that needs to be done.	0.705	
Identify team members' strengths/weaknesses and distribute tasks and workload accordingly.	0.391	
Monitor the design process to ensure goals are being met.	0.322	
Factor 7: Interdisciplinary Knowledge[2]		0.80
Indicate your level of agreement with the following statements:		
I value reading about topics outside of engineering (history, business, politics, the cultures of other parts of the world, etc.).	0.422	
I enjoy thinking about how different fields approach the same problem in different ways.	0.544	

Not all engineering problems have purely technical solutions.	0.450	
In solving engineering problems I often seek information from experts in other academic fields.	0.501	
Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.	0.567	
I see connections between ideas in engineering and ideas in the humanities and social sciences.	0.643	
I can take ideas from *outside engineering* and synthesize them in ways that help me better understand or explain a problem.	0.760	
I can use what I have learned in one field in another setting or to solve a new problem.	0.686	
Factor 8: Reflective Behavior[2]		0.67
Indicate your level of agreement with the following statements:		
I often step back and reflect on what I am thinking to determine whether I might be missing something.	0.712	
I frequently stop to think about where I might be going wrong or right with a problem solution.	0.781	

Note. All items are on a five-point Likert scale, however, not all scales are identical; 1 indicates a Likert scale of: 1 = Weak/none, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent; 2 indicates a scale of: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree; n = 5,249.

Another EFA was conducted on the 14 items related to classroom experiences on the university student survey. All items were on a five-point Likert scale as noted in Table 12. The results for this EFA are shown in Figure 5 and Table 11.

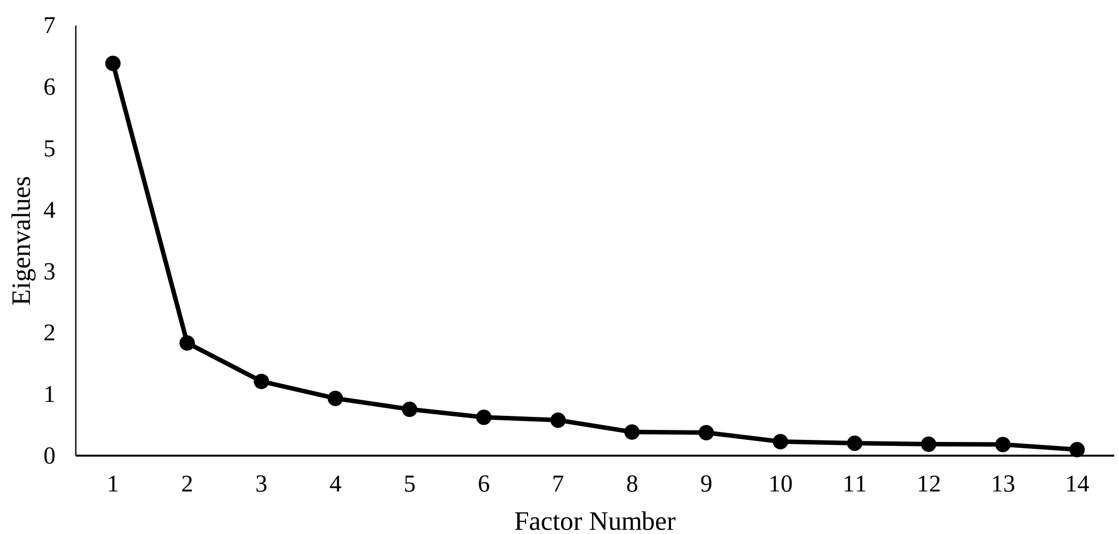

Figure 5. Scree plot for the university student survey: classroom experiences.

Based on the scree plot shown in Figure 5, a two- or three-factor model appeared to fit the data best. However, in examining the fit statistics (Table 11) for the three-factor model, there was a negative residual variance, known as a Heywood case, which indicates that the model may be misspecified (Kolenikov & Bollen, 2012). After examining the factor loadings, two items were deleted in order to address this issue.

Table 11. *Fit Statistics for the University Survey: Classroom Experiences*

Results of Initial EFA (14 Items)						
	Chi-Square					
No. of Factors	X^2	d.f.	p-value	RMSEA	RMR	Negative Residual Variance
2	12967.48	64	0.000	0.196	0.082	No
3	9402.23	52	0.000	0.185	0.068	Yes
4	5183.80	41	0.000	0.155	0.053	No
Results of Final EFA (12 Items)						
2	9326.96	43	0.000	0.203	0.077	No

Note. n = 5,249.

Another EFA was conducted on the remaining 12 items related to classroom experiences, and after examining the scree plot, fit statistics, and substantively interpretability of the factors, a two-factor model was determined to fit the data best (RMSEA = 0.203; RMR = 0.077). The two factors, along with the items loading onto each factor, the factor loadings, and the Cronbach's alpha, are shown in Table 12. As presented in the table, both factors have high reliability with Cronbach's alphas above 0.8 (Cronbach, 1951). In this dissertation, one factor, "Classroom Climate," was used in further analyses.

Table 12. Factors for the University Survey: Classroom *Experiences*

Factor and Items	Factor Loadings	Cronbach's Alpha, α
Factor 1: Classroom Climate[1]		0.90
In your engineering courses, how often do:		
Male students treat other male students better than female students.	0.691	
White students treat other white students better than non-white students.	0.954	
When working in groups, male students treat other male students better than female students.	0.696	
When working in groups, white students treat other white students better than non-white students.	0.963	
Instructors treat male students better than female students.	0.650	
Instructors treat white students better than non-white students.	0.738	
Women students get treated better than male students.	0.417	
Minority students get treated better than white students.	0.433	
Factor 2: Identity in Engineering Field[2]		0.84
Do you agree or disagree with the following:		
My gender has or will influence my choice of engineering field.	0.660	
My gender will negatively influence my engineering career.	0.810	
My race/ethnicity has or will influence my choice of engineering field.	0.757	
My race/ethnicity will negatively influence my engineering career.	0.819	

Note. All items were on a five-point Likert scale, however, not all scales were identical; 1 indicates a Likert scale of: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Very often; 2 indicates a scale of: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree; n = 5,249.

Summary of Findings

Table 13 provides a summary of findings for the four-year university student survey, including the factor name, Cronbach's alpha, mean total score, as well as, the mean score for each factor. University engineering students' perceptions of their classroom climate yielded a mean score of 4.29 (*SD* = 0.61); these students' perceptions of their fundamental skills in engineering yielded a mean score of 3.85 (*SD* = 0.71).

Table 13. *Summary of the University Survey Factors*

Factor	**α**	**Mean Total Score (s.d)**	**Mean Score (s.d.)**
Fundamental Engineering Skills	0.73	11.54 (2.14)	3.85 (0.71)
Design Skills	0.93	43.50 (8.62)	3.63 (0.72)
Contextual Awareness	0.91	13.46 (3.53)	3.36 (0.88)
Communication	0.86	22.80 (4.25)	3.80 (0.71)
Teamwork	0.85	19.64 (3.70)	3.93 (0.74)
Leadership	0.90	22.46 (4.67)	3.74 (0.78)
Interdisciplinary Knowledge	0.80	32.10 (3.80)	4.01 (0.48)
Reflective Behavior	0.67	8.05 (1.25)	4.02 (0.63)
Classroom Climate	0.90	34.32 (4.85)	4.29 (0.61)
Identity in Engineering Field	0.84	17.56 (2.77)	4.39 (0.69)

Note. n = 5,249.

1c. How do community college engineering students' perceptions of their classroom climate and fundamental engineering skills compare to and/or differ from university engineering students' perceptions?

Equating Results

While the items on the community college and university student survey were nearly the same, some of the wording of the items and the stems were not exactly the same. For example, on the community college survey, one items reads: "Please rate your ability to apply computer tools and applications to *real-world* problems." On the university survey, a similar item reads: "Please rate your ability to apply computer tools and applications to *engineering* problems." Thus, in order to compare the results from the two surveys, it was necessary to first equate the scores. Typically, equating is used to link scores on alternate forms of a test; in this study, however, the purpose of equating was to separate survey differences from group differences in order to make comparisons between the two groups. Equating analysis, employing the common-item nonequivalent groups design, was conducted using the Common Item Program for Equating (CIPE) version 2.0 (Kolen, 2004). This design of equating requires a common set of items from both surveys; the common items as well as the unique items from the two surveys are shown in Table 14.

Table 14. *Items Included in Equating Analysis*

Common Items (Form V)	
Please rate your ability to:	
Write a well-organized, coherent report.	
Make effective audiovisual presentations.	
Construct tables or graphs to communicate a solution.	
Communicate effectively with people from different cultures or countries.	
Do you agree or disagree with the following:	
My gender has or will influence my choice of engineering field.	
My gender will negatively influence my engineering career.	
My race/ethnicity has or will influence my choice of engineering field.	
My race/ethnicity will negatively influence my engineering career.	
Community College Only (Form X)	**University Only (Form Y)**
Please rate your ability to:	Please rate your ability to:
Math to real-world problems.	Math to engineering problems.
The physical sciences to real-world problems.	The physical sciences to engineering problems.
Computer tools and applications to real-world problems.	Computer tools and applications to engineering problems.
Life sciences to real-world problems.	Life sciences to engineering problems.
In your courses, do:	In your engineering courses, how often do:
Some male students treat other male students better than female students.	Male students treat other male students better than female students.
Some white students treat other white students better than non-white students.	White students treat other white students better than non-white students.
When working in groups, some male students treat other male students better than female students.	*When working in groups*, male students treat other male students better than female students.
When working in groups, some white students treat other white students better than non-white students.	*When working in groups*, white students treat other white students better than non-white students.
Some instructors treat male students better than female students.	Instructors treat male students better than female students.
Some instructors treat white students better than non-white students.	Instructors treat white students better than non-white students.
Women students get treated better than male students.	Women students get treated better than male students.
Minority students get treated better than white students.	Minority students get treated better than white students.

Table 15 provides the summary statistics for the items used in the equating analysis. Twelve unique items from the community college and university survey were included, and 8 items that were common to both surveys were included. The mean for the community college items was 80.46 (*SD* = 9.38) and for the university items was 81.71 (*SD* = 8.48). Each set of items is slightly negatively skewed (Community college: -0.53; University: -0.55; Common items: -0.37); the community college and university items have slight positive kurtosis (3.16 and 3.61, respectively) while the common items have slight negative kurtosis (2.62). The table also shows the correlation between the common items and the total mean scores for each sample; as shown, the correlations are very similar (r = 0.78 for the community college survey and r = 0.80 for the university survey) and relatively strong.

Table 15. *Summary Statistics for Community College, University, and Common Items*

	Community College (Form X)	**University (Form Y)**	**Common Items (Form V)**	
			CC	**Univ.**
Sample size	1,245	5,249	1,245	5,249
Number of items	12	12	8	8
Mean	80.46	81.71	31.30	32.62
SD	9.38	8.48	4.71	4.18
Skewness	-0.53	-0.55	-0.37	-0.52
Kurtosis	3.16	3.61	2.62	3.24
Correlation (to Form V)	0.78	0.80	-	-

In Table 16, the results for the Tucker linear equating methods are shown; the table provides the equated university survey equivalent scores for the community college data. For example, if a student had a score of 10 on the community college survey, this would be equivalent to a 10.61 on the university survey. The slope (0.979) and intercept (0.820) were used to linearly equate all of the community college survey scores to equivalent university survey scores.

Table 16. *Linear Equating Results: Selected Form Y Equivalents*

X-Score	**Tucker Linear**
10	10.61
20	20.40
30	30.19
40	39.98
50	49.76
60	59.55
70	69.34
80	79.13
90	88.92
100	98.71
Slope	0.979
Intercept	0.820

Note. Community College n = 1,245; University n = 5,249.

Summary of Findings

Table 17 provides a summary of findings, comparing the equated scores from the community college survey to the university survey. As shown, community college students' perceptions of their fundamental skills in engineering yielded a mean score of 3.72 (*SD* = 0.76), which was lower than university students' perceptions of their skills with a mean score of 3.85 (*SD* = 0.71). This difference between community college and university students' perceptions was statistically significant $t(6{,}492) = -5.98$, $p < 0.001$. Community college students' perceptions of their classroom climate, however, were higher than university students' perceptions (*M* = 4.38, *SD* = 0.69 and *M* = 4.29, *SD* = 0.61, respectively); this difference was also statistically significant $t(6{,}492) = 3.74$, $p < 0.001$.

Table 17. *Comparison of Community College and University Students' Perceptions*

	Community College Equated Mean Score (s.d.)	**University Mean Score (s.d.)**
Fundamental Engineering Skills	3.72 (0.76)	3.85 (0.71)
Classroom Climate	4.38 (0.69)	4.29 (0.61)

Note. Community College n = 1,245; University n = 5,249.

These equated scores from the community college survey were then used in the HLM analysis that follows. As suggested in Carle (2009), a sensitivity analysis comparing the equated and non-equated HLM results was conducted; results suggested that the equated results were robust and therefore the equated community college scores were used in the analysis.

2a. How are community college engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

Community College HLM Results

To address this research question, hierarchical linear modeling (HLM) was chosen due to the nested structure of the data, i.e. students nested within institutions. The two-level HLM models that were used allowed the researcher to examine variation at both the individual and the organizational level. All HLM analyses in this study were conducted using HLM 7 software (Raudenbush, Bryk, & Congdon, 2011). Level-1 units in this analysis were the individual students and the level-2 units were the community colleges. For clarity, Table 18 provides a list of all of the level-1 and level-2 variables that were included in the HLM analyses for the community college students, including a description of the variables and how they were denoted in the models.

Table 18. *Codebook for Variables in Community College HLM Models*

Variable	Description	Denoted
Student Level		
Gender	Dummy coded variable for gender; Reference group = Male	
Male	Coded: 1 = Male, 0 = Female	*DMALE*
Race/Ethnicity	Dummy coded variables for race/ethnicity; Reference group = White	
African American	Coded: 1 = African American, 0 = all others	*DBLACK*
Asian	Coded: 1 = Asian, 0 = all others	*DASIAN*
Hispanic	Coded: 1 = Hispanic, 0 = all others	*DHISP*
Other	Coded: 1 = Other, 0 = all others	*DOTHER*
Interaction Terms	Interaction terms of dummy coded gender and race/ethnicity variables.	
Male x Black	Coded: 1 = African American Male, 0 = all others	*M_B*
Male x Asian	Coded: 1 = Asian Male, 0 = all others	*M_A*
Male x Hispanic	Coded: 1 = Hispanic Male, 0 = all others	*M_H*
Male x Other	Coded: 1 = Other Male, 0 = all others	*M_O*
Parent Education Level	Dummy coded variables for parent's education level; Reference group = Parent Education High	
Parent Edu. Low	Coded: 1 = Parent Edu. Low, 0 = all others	*DPEDULOW*
Parent Edu. Mid	Coded: 1 = Parent Edu. Mid, 0 = all others	*DPEDUMID*
Discipline	Dummy coded variables for engineering discipline; Reference group = General Engineering	
Biomedical	Coded: 1 = Biomedical, 0 = all others	*CC_BIO*
Chemical	Coded: 1 = Chemical, 0 = all others	*CC_CHEM*
Civil	Coded: 1 = Civil, 0 = all others	*CC_CIVIL*
Electrical	Coded: 1 = Electrical, 0 = all others	*CC_ELEC*
General	Coded: 1 = General, 0 = all others	*CC_GEN*
Industrial	Coded: 1 = Industrial, 0 = all others	*CC_INDUS*
Mechanical	Coded: 1 = Mechanical, 0 = all others	*CC_MECH*
Other	Coded: 1 = Other, 0 = all others	*CC_OTHER*
Other Control Variables		
Credits	Number of community college credits earned to date	*CREDITS*
Age	Current age	*AGE*
High school GPA	High school GPA	*HSGPA*
School Level		
Climate	Classroom climate scale determined by EFA	*CLIM_CC*
Dependent Variable		
Fundamental Skills in Engineering	Fundamental engineering skills scale determined by EFA	*SKILL_CC*

Note. At level-1, n = 1,306 students; at level-2, n = 15 community colleges.

The first step in model building was to formulate the unconditional model in which no predictors were added to the model (equations shown in Table 19). From this fully unconditional model, the intraclass correlation (ICC) was calculated as 0.020, indicating that 2% of the variation in students' perceptions of fundamental engineering skills existed between schools. In educational research, ICC values between 0.05 and 0.20 are common. While the ICC value for this model was below that threshold, the statistically significant variance at the school level (shown in Table 20) justified the use of HLM (Snijders & Bosker, 1999).

Table 19. *HLM Models for Community College Data*

Model	**Level-1**	**Level-2**
Model A: Unconditional Model	$SKILL\_CC_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + u_{0j}$
Model B: Primary variable of interest (Classroom Climate) at Level-2	$SKILL\_CC_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_CC_j) + u_{0j}$
Model C: Primary variables of interest (race, gender, interaction of race and gender) at Level-1	$SKILLCC_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$
Model D: Both Level-1 and Level-2 variables of interest	$SKILL\_CC_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_CC_j) + u_0$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$

		$\beta_{9j} = \gamma_{90}$
Model E: Added Level-1 control covariates (number of credits earned, age, parent education, high school GPA, discipline)	$SKILL\_CC_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + \beta_{10j}*(CREDITS_{ij}) + \beta_{11j}*(AGE_{ij}) + \beta_{12j}*(DPEDULOW_{ij}) + \beta_{13j}*(DPEDUMID_{ij}) + \beta_{14j}*(HSGPA_{ij}) + \beta_{15j}*(CC\_BIO_{ij}) + \beta_{16j}*(CC\_CHEM_{ij}) + \beta_{17j}*(CC\_CIVIL_{ij}) + \beta_{18j}*(CC\_ELEC_{ij}) + \beta_{19j}*(CC\_GEN_{ij}) + \beta_{20j}*(CC\_INDUS_{ij}) + \beta_{21j}*(CC\_MECH_{ij}) + \beta_{22j}*(CC\_OTHER_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_CC_j) + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$ $\beta_{10j} = \gamma_{100}$ $\beta_{11j} = \gamma_{110}$ $\beta_{12j} = \gamma_{120}$ $\beta_{13j} = \gamma_{130}$ $\beta_{14j} = \gamma_{140}$ $\beta_{15j} = \gamma_{150}$ $\beta_{16j} = \gamma_{160}$ $\beta_{17j} = \gamma_{170}$ $\beta_{18j} = \gamma_{180}$ $\beta_{19j} = \gamma_{190}$ $\beta_{20j} = \gamma_{200}$ $\beta_{21j} = \gamma_{210}$ $\beta_{22j} = \gamma_{220}$

In order to explain the significant variation found between schools, a second model was formulated in which the classroom climate variable (CLIM_CC) was added at level-2 (Model B in Tables 19 and 20). The change in the variance component from the unconditional model represents the portion of the school-to-school variation that can be explained by classroom climate. That is, the proportion of variance explained by CLIM_CC is 0.269 [(0.01187 - 0.00868/0.01187 = 0.26874), indicating that 26.9% of the variation in schools can be explained by classroom climate.

The next step in model building was to formulate a model (Model C) with only primary Level-1 variables of interest, i.e. gender, race, and the interaction of race and gender. Comparing the residual variance in this model to the baseline model, the proportion of variance explained at Level-1 can be computed. In this case, the difference in residual variances was 0.03673 [(0.56598 – 0.54519)/ 0.56598 = 0.03673], indicating that 3.7% of within school variation of perception of fundamental engineering skills was explained by including these variables in the model.

In Model D, the primary independent variables of interest—gender, race, and the interactions of gender and race—were added at Level-1 and Classroom Climate was added at Level-2. Results from Model D indicate that male students had marginally lower perceptions of fundamental skills in engineering ($\hat{\gamma}_{10} = -0.225$, $p < 0.10$). Furthermore, Black, Asian, and Hispanic students had significantly lower perceptions of fundamental skills in engineering than White students ($\hat{\gamma}_{20} = -0.689$, $p < 0.01$; $\hat{\gamma}_{30} = -1.005$, $p < 0.001$, $\hat{\gamma}_{40} = -0.457$, $p < 0.01$, respectively); the two-way interactions of Male x Black ($\hat{\gamma}_{60} = 0.517$, $p < 0.05$) and Male x Asian ($\hat{\gamma}_{70} = 1.194$, $p < 0.001$) were also statistically significant.

In the final model, Model E, the control covariates—community college credits earned, current age, parent education level, high school GPA, and discipline—were added to the model. At Level-1, gender was marginally significant ($\hat{\gamma}_{10} = -0.223$, $p < 0.10$), indicating that male students had lower perceptions of their fundamental engineering skills. Black ($\hat{\gamma}_{20} = -0.672$, $p < 0.01$), Asian ($\hat{\gamma}_{30} = -0.943$, $p < 0.001$), Hispanic ($\hat{\gamma}_{40} = -0.514$, $p < 0.001$), and students in the "Other" category ($\hat{\gamma}_{50} = -0.464$, $p < 0.01$) had significantly lower perceptions of fundamental skills in engineering as compared to White students. In addition, all of the two-way interactions of gender by race were significant (Male x Black: $\hat{\gamma}_{60} = 0.561$, $p < 0.05$; Male x Asian: $\hat{\gamma}_{70} = 1.055$, $p < 0.001$; Male x Hispanic: $\hat{\gamma}_{80} = 0.325$, $p < 0.05$; Male x Other: $\hat{\gamma}_{90} = 0.387$, $p < 0.05$). The control covariates of Credits ($\hat{\gamma}_{100} = 0.002$, $p < 0.01$), High school GPA ($\hat{\gamma}_{140} = 0.107$, $p <$

0.001), and the discipline of Chemical Engineering ($\hat{\gamma}_{160}$ = 0.488, $p < 0.01$) were also significant predictors of perceptions of fundamental skills in engineering. The disciplines of Electrical Engineering ($\hat{\gamma}_{180}$ = -0.189, $p < 0.10$), Industrial Engineering ($\hat{\gamma}_{200}$ = 0.274, $p < 0.10$), and "Other" ($\hat{\gamma}_{220}$ = 0.195, $p < 0.10$) were marginally significant ($p < 0.10$). At level-2, the classroom climate variable was marginally significant ($\hat{\gamma}_{01}$ = 0.133, $p < 0.10$), indicating that a more positive perception of classroom climate was associated with higher perceptions' of fundamental skills in engineering.

Table 20. *Results of HLM Analysis for Community College Data*

	Model A	Model B	Model C	Model D	Model E
Fixed Effects					
Intercept, γ_{00}	3.711***	3.324***	4.017***	3.423***	3.353***
Climate, γ_{01}		0.088		0.136~	0.133~
Male, γ_{10}			-0.227~	-0.225~	-0.223~
Black, γ_{20}			-0.667**	-0.689**	-0.672**
Asian, γ_{30}			-0.993***	-1.005***	-0.943***
Hispanic, γ_{40}			-0.462**	-0.457**	-0.514***
Other, γ_{50}			-0.311~	-0.315~	-0.464**
Male x Black, γ_{60}			0.512*	0.517*	0.561*
Male x Asian, γ_{70}			1.182***	1.194***	1.055***
Male x Hispanic, γ_{80}			0.262	0.257	0.325*
Male x Other, γ_{90}			0.280	0.276	0.387*
Credits, γ_{100}					0.002**
Age, γ_{110}					0.001
Parent Edu. Low, γ_{120}					-0.081
Parent Edu. Mid, γ_{130}					-0.083
High school GPA, γ_{140}					0.107***
Biomedical, γ_{150}					0.253
Chemical, γ_{160}					0.488**
Civil, γ_{170}					-0.005
Electrical, γ_{180}					0.189~
General, γ_{190}					-0.084
Industrial, γ_{200}					0.274~
Mechanical, γ_{210}					0.146
Other, γ_{220}					0.195~
Random Effects					
Intercept, u_0	0.012***	0.009***	0.013***	0.006**	0.005**
Level-1, *r*	0.566	0.566	0.5453	0.546	0.510

Note. ~p ≤ 0.10; *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001; Level-1 n = 1,306, Level-2 n = 15.

Analysis of Model Fit

HLM has several assumptions, including a linear relationship between variables, normality of errors, and homogeneity of variance (Maas & Hox, 2004a; Raudenbush & Bryk, 2002). In order to check for linearity between variables, scatterplots of the dependent variable and the independent variables were examined, e.g. a scatterplot of fundamental skills in engineering and gender was created. Because most of the independent variables were dichotomous (i.e., for gender, male = 1 and female = 0), these scatterplots were not easily interpreted for linearity. However, after examining these scatterplots, this assumption appeared to hold.

To check for normality of errors, a Q-Q plot was created from the HLM residual file, shown in Figure 6. Under the assumption of normality, the data should be close the 45 degree reference line; in this case, most of the data points were close to the line, indicating that this assumption also holds. The homogeneity of variance test for the final HLM model supported the tenability of this assumption (χ^2 (14) = 22.261, $p < 0.10$). Lastly, there is no indication that the scores from students at one college would affect those at another college, so the assumption of independent observations holds.

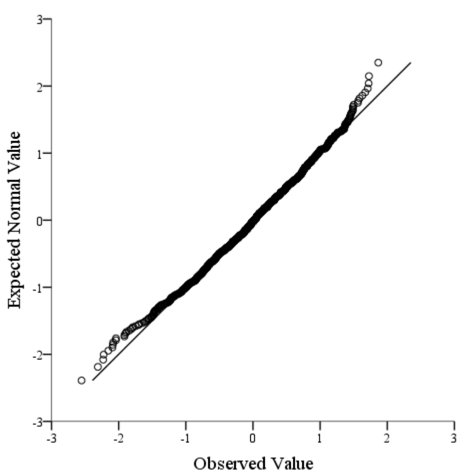

Figure 6. Q-Q plot of residuals.

Summary of Findings

As shown in the final model (Model E) in Table 20, there was a marginally significant relationship between community college engineering students' perception of their classroom climate and their fundamental skills in engineering, such that a higher, or warmer, perception of classroom climate was associated with a higher perception of their fundamental skills in engineering. Although there was significant variation between schools, the amount of variation was low, indicating that student level characteristics may explain more of the variation in the association. For community college students, gender and race were both significant predictors, with male students and minority students expressing lower perceptions of their fundamental engineering skills. All of the interactions of race by gender were also significant. In addition, several engineering disciplines were marginally significant predictors, including chemical, electrical, and industrial engineering.

2b. How are university engineering students' perceptions of their fundamental engineering skills related to their perceptions of classroom climate?

University Student HLM Results

As with the community college data, HLM analysis was used with the university student data to answer this research question. All HLM analyses were conducted using HLM 7 software (Raudenbush et al., 2011). Level-1 units in this analysis were the individual students and the level-2 units were the universities. Tables 21 and 22 provide codebooks of all of the level-1 and level-2 variables used in the university HLM models, including a description of the variables and how they were denoted in the models.

Table 21. *Codebook for Level-1 Variables in University Student HLM Models*

Variable	Description	Denoted
Student Level		
Gender	Dummy coded variable for gender; Reference group = Male	
Male	Coded: 1 = Male, 0 = Female	*DMALE*
Race/Ethnicity	Dummy coded variables for race/ethnicity; Reference group = White	
African American	Coded: 1 = African American, 0 = all others	*DBLACK*
Asian	Coded: 1 = Asian, 0 = all others	*DASIAN*
Hispanic	Coded: 1 = Hispanic, 0 = all others	*DHISP*
Other	Coded: 1 = Other, 0 = all others	*DOTHER*
Interaction Terms	Interaction terms of dummy coded gender and race/ethnicity variables.	
Male x Black	Coded: 1 = African American Male, 0 = all others	*M_B*
Male x Asian	Coded: 1 = Asian Male, 0 = all others	*M_A*
Male x Hispanic	Coded: 1 = Hispanic Male, 0 = all others	*M_H*
Male x Other	Coded: 1 = Other Male, 0 = all others	*M_O*
Parent Education Level	Dummy coded variables for parent's education level; Reference group = Parent Education High	
Parent Edu. Low	Coded: 1 = Parent Edu. Low, 0 = all others	*DPEDULOW*
Parent Edu. Mid	Coded: 1 = Parent Edu. Mid, 0 = all others	*DPEDUMID*
Discipline	Dummy coded variables for engineering discipline; Reference group = General Engineering	
Biomedical	Coded: 1 = Biomedical, 0 = all others	*S_BIO*
Chemical	Coded: 1 = Chemical, 0 = all others	*S_CHEM*
Civil	Coded: 1 = Civil, 0 = all others	*S_CIVIL*
Electrical	Coded: 1 = Electrical, 0 = all others	*S_ELEC*
General	Coded: 1 = General, 0 = all others	*S_GEN*
Industrial	Coded: 1 = Industrial, 0 = all others	*S_INDUS*
Mechanical	Coded: 1 = Mechanical, 0 = all others	*S_MECH*
Other	Coded: 1 = Other, 0 = all others	*S_OTHER*
Other Control Variables		
Age	Current age	*AGE*
SAT Score	SAT score	*SATCOMPO*
Dependent Variable		
Fundamental Skills in Engineering	Fundamental engineering skills scale determined by EFA	*SKILL_CC*

Note. At level-1, n = 5,406 students.

Table 22. *Codebook for Level-2 Variables in University Student HLM Models*

Variable	Description	Denoted
School Level		
Climate	Classroom climate scale determined by EFA	*CLIM_U*
University Size	Dummy coded variable for university size; Reference group = Large university	
Small	Coded: 1 = Small, 0 = all others	*DSMALL*
Medium	Coded: 1 = Medium, 0 = all others	*DMEDIUM*
Highest Degree Offered	Dummy coded variable for highest degree offered; Reference group = Research Institution	
Bachelor's	Coded: 1 = Bachelor's, 0 = all others	*DBACH*
Master's	Coded: 1 = Master's, 0 = all others	*DMASTERS*
Sector	Dummy coded variable for university sector; Reference group = Private	
Public	Coded: 1 = Public, 0 = all others	*DPUBLIC*
Dependent Variable		
Fundamental Skills in Engineering	Fundamental engineering skills scale determined by EFA	*SKILL_CC*

Note. At level-2, n = 31 universities.

First, an unconditional model was formulated in which no predictors were added to the model, as shown in Table 23. From this model, the ICC was calculated as 0.051, indicating that 5.1% of the variation in university students' perceptions of fundamental engineering skills was between schools. Although this value is low, in educational research ICCs between 0.05 and 0.20 are common (Snijders & Bosker, 1999). The ICC value and significant variance at the school level justified the use of HLM.

Table 23. *HLM Models for University Student Data*

Model	Level-1	Level-2
Model A: Unconditional Model	$SKILLS\_U_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + u_{0j}$
Model B: Primary variable of interest (Classroom Climate) at Level-2	$SKILL\_U_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_U_j) + u_{0j}$
Model C: Primary	$SKILLS\_U_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij})$	$\beta_{0j} = \gamma_{00} + u_{0j}$ $\beta_{1j} = \gamma_{10}$

variables of interest (race, gender, interactions of race and gender) at Level-2	$+ \beta_{3j}*(DASIAN_{ij})$ $+ \beta_{4j}*(DHISP_{ij})$ $+ \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij})$ $+ \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij})$ $+ \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$
Model D: Both Level-1 and Level-2 variables of interest	$SKILL\_U_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_U_j) + u_0$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$
Model E: Added Level-1 control covariates (age, parent education level, discipline, SAT score)	$SKILLS\_U_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + \beta_{10j}*(AGE_{ij}) + \beta_{11j}*(DPEDULOW_{ij}) + \beta_{12j}*(DPEDUMID_{ij}) + \beta_{13j}*(S\_BIO_{ij}) + \beta_{14j}*(S\_CHEM_{ij}) + \beta_{15j}*(S\_CIVIL_{ij}) + \beta_{16j}*(S\_ELEC_{ij}) + \beta_{17j}*(S\_GEN_{ij}) + \beta_{18j}*(S\_INDUS_{ij}) + \beta_{19j}*(S\_MECH_{ij}) + \beta_{20j}*(S\_OTHER_{ij}) + \beta_{21j}*(SATCOMPO_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_U_j) + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$ $\beta_{10j} = \gamma_{100}$ $\beta_{11j} = \gamma_{110}$ $\beta_{12j} = \gamma_{120}$ $\beta_{13j} = \gamma_{130}$ $\beta_{14j} = \gamma_{140}$ $\beta_{15j} = \gamma_{150}$ $\beta_{16j} = \gamma_{160}$ $\beta_{17j} = \gamma_{170}$ $\beta_{18j} = \gamma_{180}$ $\beta_{19j} = \gamma_{190}$ $\beta_{20j} = \gamma_{200}$ $\beta_{21j} = \gamma_{210}$
Model F: Added Level-2 control covariates (size,	$SKILLS\_U_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij})$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_U_j) + \gamma_{02}*(DSMALL_j) + \gamma_{03}*(DMEDIUM_j) + \gamma_{04}*(DMASTERS_j)$

highest level of degree, sector)	+ β_{7j}*(M_A_{ij}) + β_{8j}*(M_H_{ij}) + β_{9j}*(M_O_{ij}) + β_{10j}*(AGE_{ij}) + β_{11j}*($DPEDULOW_{ij}$) + β_{12j}*($DPEDUMID_{ij}$) + β_{13j}*(S_BIO_{ij}) + β_{14j}*(S_CHEM_{ij}) + β_{15j}*(S_CIVIL_{ij}) + β_{16j}*(S_ELEC_{ij}) + β_{17j}*(S_GEN_{ij}) + β_{18j}*(S_INDUS_{ij}) + β_{19j}*(S_MECH_{ij}) + β_{20j}*(S_OTHER_{ij}) + β_{21j}*($SATCOMPO_{ij}$) + r_{ij}	+ γ_{05}*($DBACH_j$) + γ_{06}*($DPUBLIC_j$) + u_{0j} $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$ $\beta_{10j} = \gamma_{100}$ $\beta_{11j} = \gamma_{110}$ $\beta_{12j} = \gamma_{120}$ $\beta_{13j} = \gamma_{130}$ $\beta_{14j} = \gamma_{140}$ $\beta_{15j} = \gamma_{150}$ $\beta_{16j} = \gamma_{160}$ $\beta_{17j} = \gamma_{170}$ $\beta_{18j} = \gamma_{180}$ $\beta_{19j} = \gamma_{190}$ $\beta_{20j} = \gamma_{200}$ $\beta_{21j} = \gamma_{210}$

To help explain this significant variation found between schools in the unconditional model, another model was formulated in which classroom climate (CLIM_U) was added to the model at level-2 (Model B in Table 24). In looking at the change in variance component from the previous model, the proportion of variance explained by CLIM_U is 0.228 [(0.02795 – 0.02157)/ 0.02795 = 0.22826). This indicates that 22.8% of the variation in schools can be explained by classroom climate. In Model C, only the primary Level-1 variables of interest, i.e. gender, race, and the interaction of race and gender, were included. The difference in residual variance between this model and the unconditional model was 0.02233 [(0.51481 – 0.50331)/ 0.51481 = 0.02233; that is, 2.2% of the within school variation was explained by these variables.

Table 24. *Results of HLM Analysis for University Student Data*

	Model A	Model B	Model C	Model D	Model E	Model F
Fixed Effects						
Intercept, γ_{00}	3.759***	3.120***	3.614***	3.049***	2.533***	2.380***
Climate, γ_{01}		0.145*		0.127*	0.085	0.119*
Small, γ_{02}						0.174
Medium, γ_{03}						0.100~
Masters, γ_{04}						-0.063
Bachelors, γ_{05}						-0.009
Public, γ_{06}						-0.036
Male, γ_{10}			0.237***	0.238***	0.223***	0.221***
Black, γ_{20}			-0.191	-0.172	-0.133	-0.145
Asian, γ_{30}			-0.048	-0.048	-0.013	-0.010
Hispanic, γ_{40}			-0.090	-0.091	-0.048	-0.046
Other, γ_{50}			-0.045	-0.039	0.002	-0.002
Male x Black, γ_{60}			0.189	0.195	0.136	0.154
Male x Asian, γ_{70}			0.052	0.050	0.057	0.059
Male x Hispanic, γ_{80}			0.032	0.029	0.023	0.030
Male x Other, γ_{90}			-0.123	-0.127	-0.051	-0.045
Age, γ_{100}					0.014***	0.014***
Parent Edu. Low, γ_{110}					-0.142	-0.142
Parent Edu. Mid, γ_{120}					0.006	0.006
Biomedical, γ_{130}					0.714*	0.708*
Chemical, γ_{140}					0.713**	0.710*
Civil, γ_{150}					0.714**	0.713*
Electrical, γ_{160}					0.813**	0.810**
General, γ_{170}					-0.055	-0.055
Industrial, γ_{180}					0.767**	0.765**
Mechanical, γ_{190}					0.859***	0.856**
Other, γ_{200}					0.908***	0.913***
SAT, γ_{210}					0.001***	0.001***
Random Effects						
Intercept, u_0	0.028***	0.022***	0.023***	0.019***	0.018***	0.012***
Level-1, r	0.515	0.515	0.503	0.503	0.458	0.458

Note. ~p ≤ 0.10; *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001; Level-1 n = 5,406, Level-2 n = 31.

In the next model, Model D, the level-1 variables of gender, race, and the interaction of gender and race, were added to the model at level-1 and classroom climate was added at level-2. Results from this model indicate that male students had significantly higher perceptions of their fundamental engineering skills ($\hat{\gamma}_{10} = 0.238$, $p < 0.001$). Black, Asian, and Hispanic students had lower perceptions of fundamental skills in engineering compared to White students, but the differences were not significant ($\hat{\gamma}_{20}$ = -0.172, p = ; $\hat{\gamma}_{30}$ = -0.048, p = , $\hat{\gamma}_{40}$ = -0.091, p = , respectively). In addition, none of the interactions between gender and race were significant predictors. Classroom climate (CLIM_U) was positively associated with students' perceptions of their fundamental engineering skills ($\hat{\gamma}_{01}$ = 0.127, $p < 0.05$), indicating that a higher perception of classroom climate was associated with a higher perception of fundamental skills in engineering.

In Model E, the level-1 control covariates were added to the model; gender, race, the interaction variables, parent education level, and discipline were added as uncentered variables, while age and SAT score were added as group mean centered variables. After controlling for these variables, gender remained a significant predictor ($\hat{\gamma}_{10}$ = 0.223, $p < 0.001$), with males reporting a higher perception of fundamental engineering skills. None of the gender or interaction variables were significant predictors. The control variables of age ($\hat{\gamma}_{100}$ = 0.014, $p < 0.001$) and SAT scores ($\hat{\gamma}_{210}$ = 0.001, $p < 0.001$) were both significant. In addition, all of the engineering disciplines, except General Engineering, were significant (Biomedical: $\hat{\gamma}_{130}$ = 0.714, $p < 0.05$; Chemical: $\hat{\gamma}_{140}$ = 0.713, $p < 0.01$, Civil: $\hat{\gamma}_{150}$ = 0.714, $p < 0.01$; Electrical: $\hat{\gamma}_{160}$ = 0.813, $p < 0.01$; General: $\hat{\gamma}_{170}$ = -0.055, $p = 0.878$; Industrial: $\hat{\gamma}_{180}$ = 0.767, $p < 0.01$; Mechanical: $\hat{\gamma}_{190}$ = 0.859, $p < 0.001$; Other: $\hat{\gamma}_{200}$ = 0.908, $p < 0.001$). Parent education level, however, was not a significant predictor (Parent Education Low: $\hat{\gamma}_{110}$ = -0.142, $p = 0.141$; Parent Education Mid: $\hat{\gamma}_{120}$ = 0.006, $p = 0.812$).

In the final model, Model F, the level-2 control variables of school size, highest degree offered, and school type, were added to the model. At level-1, gender was significant, indicating that males had higher perceptions of their fundamental engineering skills ($\hat{\gamma}_{10}$ = 0.221, $p < 0.001$). None of the race variables or the interaction variables of race and gender were significant predictors. The control variables of age ($\hat{\gamma}_{100}$ = 0.014, $p < 0.001$) and SAT scores ($\hat{\gamma}_{210}$ = 0.001, p

< 0.001) were both significant in this model as well. Similar to the previous model, all of the engineering disciplines, except General Engineering, were significant (Biomedical: $\hat{\gamma}_{130} = 0.708$, $p < 0.05$; Chemical: $\hat{\gamma}_{140} = 0.710$, $p < 0.05$, Civil: $\hat{\gamma}_{150} = 0.713$, $p < 0.05$; Electrical: $\hat{\gamma}_{160} = 0.810$, $p < 0.01$; General: $\hat{\gamma}_{170} = -0.055$, $p = 0.869$; Industrial: $\hat{\gamma}_{180} = 0.765$, $p < 0.01$; Mechanical: $\hat{\gamma}_{190} = 0.856$, $p < 0.01$; Other: $\hat{\gamma}_{200} = 0.913$, $p < 0.001$). In addition, parent education level was not a significant predictor (Parent Education Low: $\hat{\gamma}_{110} = -0.142$, $p = 0.133$; Parent Education Mid: $\hat{\gamma}_{120} = 0.006$, $p = 0.805$).

At level-2 in the final model, classroom climate was significantly associated with fundamental skills in engineering ($\hat{\gamma}_{01} = 0.119$, $p < 0.05$), such that the higher the perception of classroom climate the higher the student perceived his/her fundamental skills in engineering. The highest degree offered at the university (bachelor's, master's, or doctorate) was not a significant predictor; similarly, the type of university (public vs. private) was also not significant. School size, specifically being a medium school, was marginally significant ($\hat{\gamma}_{03} = 0.100$, $p < 0.10$).

Analysis of Model Fit

As with the community college data, the HLM assumptions were checked for the university student data. To reiterate, HLM has several assumptions: a linear relationship between variables, normality of errors, homogeneity of variance, and independence of observations (Maas & Hox, 2004a; Raudenbush & Bryk, 2002). After examining the scatterplots of the dependent and independent variables, the assumption of a linearity appeared to hold. A Q-Q plot (Figure 7) was created from the HLM residual file to check for normality of errors. Most of the data points were close to the 45 degree line, indicating that this assumption also holds. The homogeneity of variance test for the final HLM model supported the tenability of this assumption ($\chi^2 (30) = 572.801$, p < 0.001).

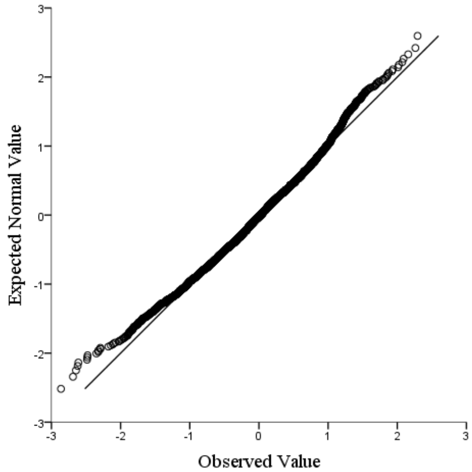

Figure 7. Q-Q plot of residuals.

University Student HLM Results – Program as Level-2

In the previous analysis of university student data, the level-1 units were the individual students and the level-2 units were the universities. In looking at the results of this analysis, each engineering discipline, except for general engineering, was a significant predictor. Thus, an additional HLM analysis was conducted with the level-2 unit as the student's engineering program, e.g. a chemical engineering department at a certain university is considered a program.

As with the previous HLM analysis, the same modeling building process (Table 25) was followed and the results are shown in Table 26. The unconditional model, Model A, yielded an ICC of 0.126, indicating that 12.6% of the variation in university students' perceptions of fundamental engineering skills was between programs. This ICC value for the previous model (0.051) was much lower, suggesting that program may be the most appropriate level-2 unit of analysis. The ICC value for this model, along with the significant variance component at the school level justified the use of HLM.

Table 25. *HLM Models for University Student Data – Program at Level-2*

Model	**Level-1**	**Level-2**
Model A: Unconditional Model	$SKILLS\_T_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + u_{0j}$
Model B: Primary variable of interest (Classroom Climate) at Level-2	$SKILLS\_T_{ij} = \beta_{0j} + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_T_j) + u_{0j}$
Model C: Primary variables of interest (race, gender, interactions of race and gender) at Level-1	$SKILLS\_T_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$
Model D: Both Level-1 and Level-2 variables of interest	$SKILLS\_T_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_T_j) + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$
Model E: Added Level-1 control covariates (age, parent education level, SAT score)	$SKILLS\_T_{ij} = \beta_{0j} + \beta_{1j}*(DMALE_{ij}) + \beta_{2j}*(DBLACK_{ij}) + \beta_{3j}*(DASIAN_{ij}) + \beta_{4j}*(DHISP_{ij}) + \beta_{5j}*(DOTHER_{ij}) + \beta_{6j}*(M\_B_{ij}) + \beta_{7j}*(M\_A_{ij}) + \beta_{8j}*(M\_H_{ij}) + \beta_{9j}*(M\_O_{ij}) + \beta_{10j}*(AGE_{ij}) + \beta_{11j}*(DPEDULOW_{ij}) + \beta_{12j}*(DPEDUMID_{ij}) + \beta_{13j}*(SATCOMPO_{ij}) + r_{ij}$	$\beta_{0j} = \gamma_{00} + \gamma_{01}*(CLIM\_T_j) + u_{0j}$ $\beta_{1j} = \gamma_{10}$ $\beta_{2j} = \gamma_{20}$ $\beta_{3j} = \gamma_{30}$ $\beta_{4j} = \gamma_{40}$ $\beta_{5j} = \gamma_{50}$ $\beta_{6j} = \gamma_{60}$ $\beta_{7j} = \gamma_{70}$ $\beta_{8j} = \gamma_{80}$ $\beta_{9j} = \gamma_{90}$ $\beta_{10j} = \gamma_{100}$ $\beta_{11j} = \gamma_{110}$ $\beta_{12j} = \gamma_{120}$ $\beta_{13j} = \gamma_{130}$

In Model B, classroom climate was added as the only predictor at level-2. The change in variance from the unconditional model indicated that 6.7% of the variation in program can be explained by the classroom climate variable. In Model C, only the primary Level-1 variables of interest, i.e. gender, race, and the interaction of race and gender, were included. The difference in residual variance between this model and the unconditional model suggests that 1.4% of the within program variation was explained by these level-1 variables.

In the next model, Model D, the level-1 variables of gender, race, and the interaction of gender and race, were added to the model at level-1 and classroom climate was added at level-2. Results from this model indicated that male students has significantly higher perceptions of their fundamental engineering skills ($\hat{\gamma}_{10} = 0.586$, $p < 0.001$). As shown in Table 23, none of the variables for gender or interactions of gender and race were significant.

Table 26. *HLM Analysis for University Student Data with Program as Level-2*

	Model A	Model B	Model C	Model D	Model E
Fixed Effects					
Intercept, γ_{00}	11.188***	9.305***	10.778***	8.901***	9.190***
Climate, γ_{01}		0.056*		0.055*	0.049*
Male, γ_{10}			0.588***	0.586***	0.677***
Black, γ_{20}			-0.392	-0.385	-0.168
Asian, γ_{30}			-0.098	-0.054	-0.008
Hispanic, γ_{40}			-0.172	-0.178	-0.018
Other, γ_{50}			-0.158	-0.173	-0.052
Male x Black, γ_{60}			0.518	0.548	0.304
Male x Asian, γ_{70}			0.133	0.090	0.132
Male x Hispanic, γ_{80}			0.059	0.062	-0.011
Male x Other, γ_{90}			0.026	0.048	-0.104
Age, γ_{100}					0.044**
Parent Edu. Low, γ_{110}					-0.434*
Parent Edu. Mid, γ_{120}					0.048
SAT, γ_{210}					0.002***
Random Effects					
Intercept, u_0	0.61321***	0.57239***	0.57988***	0.54308***	0.55153***
Level-1, r	4.24147	4.23461	4.18190	4.17445	3.97437

Note. ~p ≤ 0.10; *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001; Level-1 n = 5,406, Level-2 n = 173.

In the final model, Model E, the level-1 control covariates, parent education level, age, and SAT score, were added to the model. After controlling for these variables, gender remained a significant predictor ($\hat{\gamma}_{10} = 0.677$, $p < 0.001$), with males reporting a higher perception of fundamental engineering skills. None of the gender or interaction variables were significant predictors. The control variables of age ($\hat{\gamma}_{100} = 0.044$, $p < 0.01$), SAT score ($\hat{\gamma}_{210} = 0.002$, $p < 0.001$), and parent education low ($\hat{\gamma}_{110} = -0.434$, $p < 0.05$) were significant. The middle parent education level, however, was not significant ($\hat{\gamma}_{120} = 0.048$, $p = 0.717$).

Summary of Findings

For the university students, two HLM analyses were conducted—one with institution as the level-2 unit and one with engineering program as the level-2 unit. The results of the initial final model, with the institution as level-2, (Model F in Table 24) indicated a significant relationship between university students' perceptions of their classroom climate and their fundamental skills in engineering, such that a higher, or warmer, perception of the classroom climate was associated with a higher perception of their fundamental skills in engineering. For these students, the individual characteristic of gender was a significant predictor, while race and the interaction of gender by race were not. In contrast with the community college students, male students in universities had higher perceptions of their fundamental skills than female students. All of the engineering disciplines, aside from general engineering, were significant. This result, along with support from the literature (Knight et al., 2012; Lattuca et al., 2010), led to an additional HLM analysis with engineering program as the level-2 unit.

As shown in Table 26, the final model (Model E) indicated that perception of classroom climate was significantly, positively associated with perception of fundamental skills in engineering. The ICC value for this analysis was comparatively high, indicating that a relatively large proportion of the variation in this association was between programs. Again in this model, gender was the only significant predictor for university students; race and the interaction of gender and race were not significant. The control variables of age, SAT score, and low parent educational background were also significant predictors.

Chapter 5: Discussion and Conclusions

In this study, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. The purpose of this study was to examine engineering students' perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering. This chapter of the dissertation includes a summary of the key findings, discussion and implications of these findings, limitations, areas for future research, as well as conclusions.

Summary of Findings

To address the first set of research questions in this study, an exploratory factor analysis (EFA) was conducted on both the community college and university student surveys. After determining constructs for perceptions of classroom climate and fundamental engineering skills through this analysis, the scores from the community college survey were linearly equated to the scores of the university survey to allow for comparisons. Results indicated that university students had higher perceptions of their fundamental engineering skills as compared to community college students. Community college engineering students, however, perceived their classroom climates as warmer than university engineering students.

To address the second set of research questions regarding the association between classroom climate and fundamental engineering skills, hierarchical linear modeling (HLM) analyses were conducted. For the community college students, a warmer perception of classroom climate was associated with a higher perception of fundamental engineering skills. Although there was significant variation between schools, the amount of variation was low, indicating that student level characteristics may explain more of the variation in the association. At the individual level, gender and race were significant predictors, with males and minority students expressing lower perceptions of their fundamental engineering skills; the interactions of gender and race were all significant as well, indicating that the association between gender and perceptions of fundamental engineering skills depends on race. In the community college model, only a few disciplines were significant predictors.

Similar to the community college students, for the university students, a warmer perception of classroom climate was associated with higher perceptions of fundamental engineering skills. At the individual level, only gender was a significant predictor, while the main effects of race and the interaction effects of gender and race were not significant. In contrast with the community college results, male students in universities had higher perceptions of their fundamental engineering skills than female students. All of the engineering disciplines, aside from general engineering, were significant. This result, along with support from the literature (Knight et al., 2012; Lattuca et al., 2010), led to an additional HLM analysis with engineering program as the highest unit.

As with the previous two models, for the university student analysis with program as the highest level, a warmer perception of classroom climate was associated with higher perceptions of fundamental engineering skills. Results from this model indicated that the highest percentage of variation in fundamental skills in engineering was at the program level. Again in this analysis, at the individual level, only gender was a significant predictor, while the main effects of race and the interaction effects of gender and race were not significant. Results suggested that male university engineering students had higher perceptions of their fundamental engineering skills as compared to female engineering students.

Limitations

As with any research involving survey data, there were several limitations to the current study. For one, this study was focused on self-reported, indirect measures of information from students regarding their perceptions of classroom climate as well as their self-reported skills and abilities; this could influence the results if students' perceptions of their abilities are not aligned with their actual abilities. Direct measures, such as administering a math exam to measure math ability or obtaining college transcripts for GPAs, could strengthen the generalizability of a study, but are often not part of a feasible study design and researchers use self-reported variables as proxies (Fredricks & McColskey, 2012; Pike, 1995). Some researchers (e.g. Kuncel, Credé, & Thomas, 2005) have found that self-reported variables, such as GPA, are more valid for students with higher ability; however, other researchers support the use of self-reported data when direct measures are not available (Fredricks & McColskey, 2012; Pike, 1995).

Another limitation of this study was the response rate for the survey, which was about 15% for the two-year student data and 16% for the four-year student data. Although this is not uncommon in survey research to have a low response rate (Porter, & Umbach, 2006; Sax, Gilmartin, & Bryant, 2003), this may also influence the generalizability of the results. The students who chose to respond to the survey may have attributes that are different than the general population of engineering undergraduate students at the time, a concept known as selection bias/non-response bias (Pedhazur & Schmelkin, 1991). To account for this limitation, researchers in the original P2P study applied sample weights and imputed data, techniques that were described in more detail in Chapter 3 of this dissertation.

In addition, the study design was cross-sectional, allowing for observations at only one point in time. Because of this, causal inferences are limited in a cross-sectional design (Levin, 2006; Pedhazur & Schmelkin, 1991). Lastly, data for this study was collected as part of another research study mentioned earlier, P2P. The current study therefore involved secondary data analysis, limiting the researcher to the variables available in the dataset.

In analyzing the community college data through HLM, the small sample size may have also been a limitation. With only 15 community colleges serving as the highest nested unit, the resulting standard errors may have been biased (Maas & Hox, 2004b). As a rule of thumb, Maas and Hox (2004b) suggest that if researchers are interested in contextual effects, as was the case in this dissertation, it is best to have 30 or more groups; if the researchers are interested in the fixed effects only, 10 groups will suffice. The small sample size at the group level does not, however, affect the coefficients (Maas & Hox, 2005).

Discussion

The discussion of key findings summarized above is organized around three main topic areas to which the results can be applied: (1) Conceptual Framework, (2), Engineering Education, and (3) Engineering Education Research. In each of these areas, the results of the study are interpreted by the researcher and supported by literature.

Discussion: Conceptual Framework

In all of the hierarchical linear models in this study, results indicated that a warmer perception of classroom climate was associated with a higher perception of fundamental engineering skills—a finding that supports and extends the literature on stereotype threat. As described in the literature review, stereotype threat was first defined by Steele and Aronson (1995) as “being at risk of confirming, as self-characteristic, a negative stereotype about one’s group” (p. 797). The concept of stereotype threat was developed through a series of studies in which various groups of students were given standardized tests; prior to taking the tests, students were told that the purpose of the test was either: (1) a diagnostic measure of their intellectual ability, (2) a non-diagnostic test, or (3) a challenge test (Steel & Aronson, 1995). Results of these studies indicated that black students performed worse on the test when told it was a diagnostic measure of intellectual ability (i.e. the stereotype condition), but performed the same as white students under the other two conditions (Steel & Aronson, 1995). Although most studies of stereotype threat are conducted at the individual level (e.g. Steel, 1997; Steel & Aronson, 1995), in this study, the concept was used in support of classroom-level associations. A chiller classroom climate, in a sense, was a measure of a stereotype threat condition, which in this study was associated with lower perceptions of fundamental skills in engineering.

In order to create engineering classroom climates that are low in stereotype threat, or warmer in climate, Steele (1997) had several recommendations, including: (1) positively affirming the student's potential to achieve in the subject, (2) assigning all students challenging assignments, which may reinforce to the student that he or she has potential and is not viewed through a stereotypical lens, (3) emphasizing the students' belongingness based on his or her intellectual potential, and (4) valuing multiple perspectives and approaches in the classroom. By reducing stereotype threat at the classroom level, students in this climate may have higher perception of their abilities, which could encourage persistence in engineering.

In this study, Terenzini and Reason's (2005) conceptual framework supported the methodological concerns regarding predictive and control variables to include in the statistical models. As suggested in the framework, students' precollege characteristics and experiences shape their interactions with their environment, and peers and faculty in that environment, while in college. As such, in this study, the sociodemographic traits of gender, race, the interaction of gender and race, current age, as well as parent education level were included as predictors in the models. In addition, students' academic preparation in high school, as measured by high school GPA for community college students and SAT scores for the university students, were also controlled for in the statistical analyses.

Results from this study supported Terenzini and Reason's (2005) conceptual framework, in that, for the community college models, gender, race, and the interaction of gender and race were all significant predictors; age and parent education level were not significant. The initial university student models also provided support for this theory given that gender, race, current age, and SAT scores were significant predictors, while parent education level and the interaction terms were not. With program as the highest nested level for the university models, gender, age, and parent education level were significant, while race and the interaction terms were not, again supporting this conceptual framework. Although not all of the sociodemographic variables and variables related to students' academic preparation in high school were significant, Terenzini and Reason's (2005) framework identifies a broad range of constructs that may influence student outcomes, but does not prescribe which to apply in a given scenario.

Discussion: Engineering Education

Results from this study indicated that university students had higher perceptions of their fundamental skills in engineering as compared to community college students. Previous research suggests that many engineering community college students, as well as engineering transfer students, have to complete a lower-level math course before taking a college-level calculus course (Terenzini et al., 2014), which could explain the lower perceptions of their fundamental engineering abilities. In a qualitative study of engineering transfers, Mobley, Shealy, and Brawner (2012) found that one reason students began their studies at another institution was because they were originally denied admission to their current university; if community college students were originally denied admission to a university, this could also explain their lower perceptions of their fundamental engineering skills.

Community college engineering students in this study, however, perceived their classroom climates as warmer than university engineering students. As noted in the literature, engineering classrooms are often characterized as male-normed and competitive, in some cases so much so that they are seen as “weed-out” systems (Seymour & Hewitt, 1997). A traditional introductory engineering class at a research university is likely to be large and lecture-based, which some students may not respond well to (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). At community colleges, class sizes are generally smaller, especially compared to introductory courses at universities (Townsend & Wilson, 2006), which may contribute to the perceptions of a warmer classroom climate.

In addition to the significant variation between schools or programs in the HLM analyses, there was significant variation in student level characteristics in predicting perceptions of fundamental skills in engineering. For the community college students, the interactions of gender and race were all significant, indicating that the association between gender and perceptions of fundamental engineering skills depends on race. For the university students, only gender was a significant predictor, while the main effects of race and the interaction effects of gender and race were not significant. The significant interaction effects for the community college sample could be attributed to the diversity of the sample (i.e. 23% Hispanic and 16% African American); likewise, the nonsignificant interaction effects for the university sample could be attributed to the relatively few students in certain race categories (i.e. 11% Hispanic and 4% African American). In the university sample, male students reported higher perceptions of their fundamental engineering skills than female students, which is consistent with the literature (Hill et al., 2010; Marra, Rodgers, Shen, & Bogue, 2009).

Discussion: Engineering Education Research

In modeling the association between classroom climate and fundamental skills in engineering for university students, the first analysis was conducted with the institution as the highest nested unit. The results showed that all of the disciplines were significant predictors of perceived fundamental engineering skills, leading to another model with discipline as the highest nested unit (i.e. the biomedical engineering discipline within the university). Results from this model indicated that a higher percentage of variation in fundamental skills in engineering was at the program level, rather than the institution level. This suggests that in future hierarchical modeling analyses, the variation in programs may be more meaningful than the variation found between universities. This finding is in line with previous research, described below, but it is unique in that contributes supporting results from HLM analyses.

Previous research supports studying differences in engineering program specialties as opposed to engineering departments/schools as a whole (Lattuca et al., 2010; Knight et al., 2012; Smart, Feldman, & Ethington, 2000). These studies are built on Holland’s (1997) theory of occupations and environments, in which Holland theorizes that people chose a given occupation based on their personality type categorized as: (1) realistic, (2), investigative, (3) artistic, (4) social, (5) enterprising, and (6) conventional. As suggested by the theory, people tend to flourish in a work environment that closely aligns with their personality type and abilities. Smart et al. (2000) applied this theory to study academic fields and found “abundant evidence…that faculty in academic departments, classified according to the six academic environments proposed by Holland, differ in ways theoretically consistent with the postulates of Holland's theory” (p. 83).

Their findings indicate that studying academic environments in terms of broad categories, such as "engineering" or "psychology" may mask variations of individuals who work within these disciplines.

Lattuca et al. (2010) also applied Holland's typology in order to examine variations in engineering faculty members' responses to changes in curricular requirements. Employing data from 1,272 faculty members in 203 engineering programs across 39 universities, they found that "disciplinary environments are important factors in shaping faculty members' attitudes and behaviors while also suggesting the value of analysis at the subdiscipline level whenever possible" (Lattuca et al., 2010, p.37).

This study also contributed to engineering education research in that, through multiple EFAs on data from both community colleges and four-year universities, a scale for measuring Classroom Climate was validated. Although several other scales exist, such as the Perceived Chilly Climate for Women Scale (Pascarella et al., 1997) and the Perceived Chilly Climate Scale (Janz & Pyke, 2000), this study presented a succinct scale focusing on how women and minority students are treated in the classroom.

Areas for Future Research

In this study, the design was cross-sectional, allowing for observations of classroom climate and fundamental skills in engineering at only one point in time. Because of this design, causal inferences were limited (Levin, 2006; Pedhazur & Schmelkin, 1991). Future research in this area could be focused on the longitudinal effects of classroom climate and other student outcomes, such as persistence in engineering. In particular, researchers could track students who begin their engineering degrees at community college and continue to a degree at a four-year university, observing how their perceptions of their engineering abilities and classroom climates change over time.

Another possible area for future research is studying classroom climate, especially in community colleges, through the lens of intersectionality. “Intersectionality is a theoretical framework for understanding how multiple social identities such as race, gender, sexual orientation, SES, and disability intersect at the micro level of individual experience to reflect interlocking systems of privilege and oppression…at the macro social-structural level” (Bowleg, 2012, p. 1267). Although only addressed briefly in this study through the use of interaction terms, the framework of intersectionality was supported by the significance of these interactions for the community college students. There were no significant interaction effects in the university sample, however, there are other aspects of intersectionality that were not addressed here, such as gender and SES group, which may have played a role in the university sample.

Conclusions

In this dissertation, the focus was on the classroom climate of engineering students in the context of either their community college or their four-year university. Previous research on the classroom climate for STEM majors suggests that women and minorities may experience a “chilly climate” and find the classroom unwelcoming; this negative climate may in turn have an impact on a student’s success or persistence in attaining a degree. The purpose of this study was to examine engineering students’ perceptions of their classroom climate and how these perceptions are related to fundamental skills in engineering.

Results from this study indicated that perceptions of engineering ability were related to classroom climate, such that warmer climates were associated with higher perceptions of ability, supporting the importance of climate in engineering classrooms. By creating a warmer classroom climate, students may have higher perceptions of their engineering abilities, which could provide the needed reassurance to persist in engineering. Results also indicated that community college engineering classrooms tended to have warmer climates than university engineering classrooms. This finding is promising in that students at community colleges may be encouraged to pursue engineering based on the climate. Although this study was limited by its cross-sectional design, future studies could expand on this study to explore community college students longitudinally to see if their perceptions of climate change once they transfer to a four-year university.

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Appendices

Appendix A: Community College Survey

PENNSTATE

Center for the Study of Higher Education

Preparing the Engineer of 2020

Community and Two-Year College Survey

This study is funded by the National Science Foundation
and endorsed by the following associations and
professional engineering societies:

Preparing the Engineer of 2020
Community and Two-Year College Survey

1. How likely is it that you will transfer to a four-year college or university <u>and</u> enroll in a bachelor's degree program in engineering?

- O Definitely will
- O Probably will
- O Not sure
- O Probably won't
- O Definitely won't

> **If you have answered "Probably won't" or "Definitely won't" you have given us the information we need. Please return the survey in the enclosed envelope. There is no need to complete additional questions.**

PERSONAL INFORMATION

2. Number of community or two-year college credits earned to date (including current registration): ☐☐☐ credits

3. In what engineering field are you most likely to get your bachelor's degree?

- O Haven't decided
- O Bio-medical/bio-engineering
- O Chemical engineering
- O Civil engineering
- O Electrical engineering
- O General engineering or engineering science
- O Industrial engineering
- O Mechanical engineering
- O Other engineering discipline (please specify): ____________________

4. Have you attended any other colleges or universities prior to this one?

- O No, this is the first college I have attended.
- O Yes, I attended another two-year college
- O Yes, I attended a four-year college or university
- O Yes, I attended a vocational school (truck driving school, cosmetology, etc.).

5. What is your gender?

- O Man
- O Woman

6. How old:		
a. Are you now?	☐☐	years
b. Were you when you first entered college anywhere?	☐☐	years
c. Were you when you entered this community or two-year college?	☐☐	years
d. Do you think you will be when you complete your bachelor's degree?	☐☐	years

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7. Are you: (select all that apply)

- O African American
- O Asian American
- O Hispanic/Latino/a American
- O Native American
- O Caucasian
- O Foreign national (i.e., citizen of another country)
- O Naturalized U.S. citizen
- O Other (please specify): ____________________

8. What is the highest level of formal schooling that you and each of your parents/guardians have competed? (Mark ONLY ONE oval per column).	You	Mother/ Guardian	Father/ Guardian
a. Did not finish high school	O	O	O
b. High school graduate/GED	O	O	O
c. Attended college but did not receive a degree	O	O	O
d. Vocational/technical certificate or diploma	O	O	O
e. Associate or other 2-year degree	O	O	O
f. Bachelor's or other 4-year degree	O	O	O
g. Master's degree (M.A., M.S., M.B.A., etc.)	O	O	O
h. Doctorate degree (Ph.D., J.D., M.D., etc.)	O	O	O

9. Did you take the SAT or ACT tests? (Please select all that apply.)

O No. I did not take either exam.

O Yes, I took the SAT exam, and my scores were approximately:
SAT Critical Reading [| |] SAT Writing [| |] SAT Math [| |]

O Yes, I took the ACT exam, and my Composite score was approximately: [|]

10. What was/is your approximate overall academic average in high school and community or two-year college?

	High School	Community or Two-Year College
a. 1.49 or below (below C-)	O	O
b. 1.50 - 1.99 (C- to C)	O	O
c. 2.00 - 2.49 (C to B-)	O	O
d. 2.50 - 2.99 (B- to B)	O	O
e. 3.00 - 3.49 (B to A-)	O	O
f. 3.50 or above (A- to A)	O	O
g. Not applicable	O	O

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ACADEMIC SKILLS

<u>Instructions</u>: In the following section, you will be asked to rate your skill level and abilities in a variety of areas. If you're unfamiliar with, or have had no experience with, any of these, select the "Weak/none" option.

11. Applying Math & Science. **Please rate your ability to apply:**	**Weak/ None**	**Fair**	**Good**	**Very Good**	**Excellent**
a. Math to real-world problems.	O	O	O	O	O
b. The physical sciences to real-world problems.	O	O	O	O	O
c. Computer tools and applications to real-world problems.	O	O	O	O	O
d. Life sciences to real-world problems.	O	O	O	O	O
12. Problem-Solving Considerations. **Please rate your:**	**Weak/ None**	**Fair**	**Good**	**Very Good**	**Excellent**
a. Knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to a problem.	O	O	O	O	O
b. Knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit.	O	O	O	O	O
c. Ability to use what you know about different cultures, social values, or political systems in developing problem solutions.	O	O	O	O	O
d. Ability to recognize how different contexts can change a problem solution.	O	O	O	O	O
13. Communication. **Please rate your ability to:**	**Weak/ None**	**Fair**	**Good**	**Very Good**	**Excellent**
a. Write a well-organized, coherent report.	O	O	O	O	O
b. Make effective audiovisual presentations.	O	O	O	O	O
c. Construct tables or graphs to communicate a solution.	O	O	O	O	O
d. Make myself understood in conversations with others.	O	O	O	O	O
e. Communicate effectively with people from different cultures or countries.	O	O	O	O	O

14. Teamwork. Please rate your ability to:	Weak/ None	Fair	Good	Very Good	Excellent
a. Work with others to accomplish group goals.	O	O	O	O	O
b. Work in teams of people with a variety of skills and backgrounds.	O	O	O	O	O
c. Work in teams where knowledge and ideas from multiple fields must be applied.	O	O	O	O	O
15. Leadership. Please rate your ability to:	**Weak/ None**	**Fair**	**Good**	**Very Good**	**Excellent**
a. Help your group or organization work through periods when ideas are too many or too few.	O	O	O	O	O
b. Develop a plan to accomplish a group or organization's goals.	O	O	O	O	O
c. Take responsibility for group or organizational performance.	O	O	O	O	O
d. Motivate people to do the work that needs to be done.	O	O	O	O	O

PROGRAM EMPHASES

16. Applying Math & Science. Overall, how much have the courses you've taken emphasized each of the following:	Little/No Emphasis	Slight Emphasis	Moderate Emphasis	Strong Emphasis	Very Strong Emphasis
a. Applying math to solve real-world problems.	O	O	O	O	O
b. Applying physical sciences to real-world problems.	O	O	O	O	O
c. Applying life sciences to real-world problems.	O	O	O	O	O
d. Designing and carrying out experiments.	O	O	O	O	O
e. Using computer tools and applications.	O	O	O	O	O
17. Professional Skills. Overall, how much have the courses you've taken emphasized each of the following:	**Little/No Emphasis**	**Slight Emphasis**	**Moderate Emphasis**	**Strong Emphasis**	**Very Strong Emphasis**
a. Professional skills (being on time, meeting deadlines, etc.).	O	O	O	O	O
b. Written and oral communication skills.	O	O	O	O	O
c. Leadership skills.	O	O	O	O	O
d. Working effectively in teams.	O	O	O	O	O

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18. Other Topics. Overall, how much have the courses you've taken emphasized each of the following:	Little/No Emphasis	Slight Emphasis	Moderate Emphasis	Strong Emphasis	Very Strong Emphasis
a. Ethical issues in engineering practice.	O	O	O	O	O
b. The importance of life-long learning.	O	O	O	O	O
c. Examining my beliefs and values and how they affect my ethical decisions.	O	O	O	O	O
d. The value of gender, racial/ethnic, or cultural diversity in the workplace.	O	O	O	O	O
e. Creativity and innovation.	O	O	O	O	O
f. Current workforce and economic trends (globalization, outsourcing, etc.).	O	O	O	O	O
g. Emerging engineering technologies.	O	O	O	O	O
h. How theories are used in engineering practice.	O	O	O	O	O

19. During the past year, approximately how many times did you:	0	1-3	4-6	7-10	11 or more
a. Use the services of a "learning/tutoring" center at your community or two-year college.	O	O	O	O	O
b. Speak to an advisor or instructor at your community or two-year college about transferring to a four-year college.	O	O	O	O	O
c. Speak to an advisor or instructor at a four-year college about transferring.	O	O	O	O	O
d. Attend a presentation by someone from a four-year college about transfer requirements and procedures.	O	O	O	O	O

20. How much do you rely on the following for help selecting courses and planning your academic program?	Little/ Not at All	Somewhat	Moderately	A Great Deal
a. Advising center staff	O	O	O	O
b. My official faculty advisor	O	O	O	O
c. A faculty member who is *not* my official advisor	O	O	O	O
d. Students in my program	O	O	O	O
e. Family and non-school friends	O	O	O	O
f. Web sites	O	O	O	O

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21. How much do you rely on the following for information <u>on how to transfer to a four-year institution</u>?	Little/ Not at All	Somewhat	Moderately	A Great Deal
a. Advising center staff	O	O	O	O
b. My official faculty advisor	O	O	O	O
c. A faculty member who is *not* my official advisor	O	O	O	O
d. Students in my program	O	O	O	O
e. Family and non-school friends	O	O	O	O
f. Web sites	O	O	O	O

22. <u>During the past six months</u>, approximately how many times did you meet outside of class with a faculty member to: (count only conversations of 10 minutes or more)	
a. Discuss academic or course-related matters	☐☐ times
b. Ask about careers or get professional advice	☐☐ times
c. Talk informally	☐☐ times

23. What was the first math course you completed in college?

- O Math required prior to algebra
- O Another math course (algebra, geometry, trigonometry, pre-calculus, etc.)
- O Calculus or above

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24. In courses at your community or two-year college, how often have your instructors:	Never	Rarely	Some-times	Often	Very Often
a. Set clear expectations for performance	O	O	O	O	O
b. Only covered what was in the textbook	O	O	O	O	O
c. Conveyed the same material in multiple ways (in writing, diagrams, orally, etc.)	O	O	O	O	O
d. Explained new concepts by linking them to what students already know	O	O	O	O	O
e. Used examples, cases, or metaphors to explain concepts	O	O	O	O	O
f. Answered questions or gone over material until students "got it"	O	O	O	O	O
g. Provided guidance or training in how to work effectively in groups	O	O	O	O	O
h. Lectured	O	O	O	O	O
i. Provided hands-on activities and/or assignments	O	O	O	O	O
j. Used in-class, small group learning	O	O	O	O	O
k. Assigned group projects	O	O	O	O	O

25. In your courses, do:	Never	Rarely	Some-times	Often	Very Often
a. Some male students treat other male students better than female students	O	O	O	O	O
b. Some white students treat other white students better than non-white students	O	O	O	O	O
c. *When working in groups*, some male students treat other male students better than female students	O	O	O	O	O
d. *When working in groups*, some white students treat other white students better than non-white students	O	O	O	O	O
e. Some instructors treat male students better than female students	O	O	O	O	O
f. Some instructors treat white students better than non-white students	O	O	O	O	O
g. Women students get treated better than male students.	O	O	O	O	O
h. Minority students get treated better than white students.	O	O	O	O	O

26. Please indicate your level of agreement with each of the following statements:	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
a. My gender has or will influence my choice of engineering field.	O	O	O	O	O
b. My gender will negatively influence my engineering career.	O	O	O	O	O
c. My race/ethnicity will negatively influence my choice of engineering field.	O	O	O	O	O
d. My race/ethnicity will negatively influence my engineering career.	O	O	O	O	O

ENGINEERING TRANSFER ISSUES

27. Why might you choose a major other than engineering? (select all that apply)

- O Lack of employment in engineering
- O Difficulty of engineering courses
- O Not able to get into engineering program
- O More credits transfer into other majors
- O Lack of engineering transfer agreement
- O Engineering takes longer than other majors
- O Engineering tuition is more expensive than other majors
- O Lack of gender or racial/ethnic diversity in engineering

28. How important were the following in your decision to begin your degree at a community or two-year college:	Not at All	Slightly	Moderately	Very	Extremely
a. Cost	O	O	O	O	O
b. Close to home/family/friends	O	O	O	O	O
c. I knew I would get in	O	O	O	O	O
d. I applied but wasn't accepted to a four-year school	O	O	O	O	O
e. Received financial aid	O	O	O	O	O
f. Family/work obligations	O	O	O	O	O
g. Flexible course scheduling (evenings, weekends)	O	O	O	O	O
h. On-campus childcare	O	O	O	O	O
i. English as a Second Language program	O	O	O	O	O
j. Transfer agreement with a four-year engineering program	O	O	O	O	O
k. Diverse student population	O	O	O	O	O
l. Good place to find out if I was ready for college-level courses	O	O	O	O	O

29. How important will the following be to you in deciding whether to transfer to a four-year engineering program:	Not at all Important	Slightly Important	Moderately Important	Very Important	Extremely Important
a. Number of credits that will transfer	O	O	O	O	O
b. Availability of transfer advisors at my college	O	O	O	O	O
c. Good information on transferring	O	O	O	O	O
d. Visiting the four-year school	O	O	O	O	O
e. Speaking with an advisor at the four-year school	O	O	O	O	O
f. Meeting with instructors or sitting in on classes at the four-year school	O	O	O	O	O
g. Talking with students at the four-year school	O	O	O	O	O

30. How much of a problem would the following be in transferring to a four-year college or university engineering program? Please answer even if you are not sure you will transfer.	Not a Problem	Minor Problem	Big Problem	Major Roadblock
a. Long commute or need to relocate	O	O	O	O
b. Cost of attendance	O	O	O	O
c. Need to quit or reduce hours on current job(s)	O	O	O	O
d. High academic expectations	O	O	O	O
e. Family obligations	O	O	O	O
f. The transfer credit process	O	O	O	O
g. Not sure the faculty, staff, or students will make me feel welcome	O	O	O	O
h. My English language skills	O	O	O	O
i. Large size of engineering school	O	O	O	O
j. Students compete rather than help one another	O	O	O	O
k. Length of time needed to complete a bachelor's degree	O	O	O	O

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31. **How likely are you to complete an associate's degree before transferring?**

O Definitely won't O Probably won't O Not sure O Probably will O Definitely will

32. **How many <u>more</u> years do you think you will need to complete your bachelor's degree in engineering?** [ ][ ] years

ADDITIONAL INFORMATION

33. In a typical week, how many hours do you spend:	
a. Preparing for class (studying, doing homework or lab work, and other academic activities)	[ ][ ] hours/week
b. Working for pay	[ ][ ] hours/week
c. Meeting family responsibilities (care of siblings, children, other family members	[ ][ ] hours/week
d. Commuting to and from school or work	[ ][ ] hours/week

34. **Have you been enrolled at your current institution primarily:**

O Full-time
O Part-time

35. **Are you currently:**

a. Taking classes at a 4-year institution? O Yes O No

b. In a formal dual-enrollment program with a 4-year institution? O Yes O No

36. **Not counting yourself, how many individuals are financially dependent on you (including children, parents, and other adults)?**

- O None
- O 1
- O 2
- O 3
- O 4 or more

37. **Is English your native language?** O Yes O No

38. **Have you had to <u>repeat</u> one or more college courses in any of the following areas?**	**Yes**	**No**
a. Chemistry	o	o
b. Engineering	o	o
c. English/communications	o	o
d. Mathematics	o	o
e. Physics	o	o

Thank you *very* much for your participation!

Please return the survey in the postage-paid envelope provided or mail to:

Penn State University
Survey Research Center
605 Marion Place
University Park, PA 16802

Appendix B: University Student Survey

Center for the Study of Higher Education

Welcome UNIVERSITY students!

Thanks for checking us out! We need your help. The National Academy of Engineering has identified the knowledge and skills that engineers will need to succeed in the workplace of the future. This National Science Foundation-funded study is designed to benchmark the current state of undergraduate engineering education and find out if we're making progress toward those goals. To do that, we're surveying students at 35 colleges and universities around the country. (You can find out who else is participating at http://www.ed.psu.edu/educ/e2020/p2p-participating-institutions.)

We know you're busy, so we will really appreciate your help. We also think you may find completing this survey a good opportunity to reflect on your engineering education to-date.

The next page outlines your rights as a research participant and provides more details on the study.

This study is funded by the National Science Foundation and endorsed by the following associations and professional engineering societies:

PENNSTATE

Center for the Study of Higher Education

Educating the Engineer of 2020 Student Survey

Personal Information

1. **What is your current class standing?**
   - ❍ First-year student
   - ❍ Sophomore
   - ❍ Junior
   - ❍ Senior
   - ❍ Fifth-year student or higher

2. **What is your major?**
   - ❍ Undecided/undeclared in engineering
   - ❍ Bio-medical or Bio-engineering
   - ❍ Chemical Engineering
   - ❍ Civil Engineering
   - ❍ Electrical Engineering
   - ❍ General Engineering/Engineering Science
   - ❍ Industrial Engineering
   - ❍ Mechanical Engineering
   - ❍ Other engineering discipline (please specify): ______________________________

3. **When you entered this institution, were you:**
   - ❍ A first-time college student
   - ❍ A transfer student from a community or two-year college
   - ❍ A transfer student from a four-year institution
   - ❍ A "3+2 program" with a four-year institution

4. **What is your gender?**
   - ❍ Man
   - ❍ Woman

5. **How old:**

   Are you now? ________

   Were you when you first entered college? ________

   Do you think you will be when you complete your bachelor's degree? ________

6. **Are you: (check all that apply)**

❑ African American	❑ Caucasian/White
❑ Asian American	❑ Foreign national (i.e., citizen of another country)
❑ Hispanic/Latino/a American	❑ Naturalized U.S. citizen
❑ Native American	❑ Other (please specify) ____________________

7. **What is the highest level of formal schooling that you and each of your parents/guardians have completed?**

	Mother/Guardian	Father/Guardian
Did not finish high school	❍	❍
High school graduate/GED	❍	❍
Attended college but did not receive a degree	❍	❍
Vocational/technical certificate or diploma	❍	❍
Associate or other 2-year degree	❍	❍
Bachelor's or other 4-year degree	❍	❍
Master's degree (M.A., M.S., M.B.A., etc	❍	❍
Doctorate degree (Ph.D., J.D., M.D., etc.)	❍	❍

8. **Did you take the SAT or ACT tests? (Please respond to all that apply)**

❑ No. I did not take either exam.

❑ Yes, I took the SAT exams, and my scores were approximately:

SAT Critical Reading ________

SAT Writing ________

SAT Math ________

❑ Yes, I took the ACT exam, and my composite score was approximately________

9. **What was/is your approximate academic average in:**

	High School	Your engineering program
1.49 or below (Below C-)	❍	❍
1.50-1.99 (C- to C)	❍	❍
2.00-2.49 (C to B-)	❍	❍
2.50-2.99 (B- to B)	❍	❍
3.00-3.49 (B to A-)	❍	❍
3.50-4.00 (A- to A)	❍	❍
Not applicable	❍	❍

Center for the Study of Higher Education

ENGINEERING SKILLS

<u>Instructions</u>: In the following section, you will be asked to rate your skill level and abilities in a variety of areas. If you're unfamiliar with, <u>or have had no experience with</u>, any of these, select the "Weak/none" option.

10. <u>Applying Math & Science</u>. Please rate your ability to apply:

	Weak/ none	Fair	Good	Very Good	Excellent
Math to engineering problems	❍	❍	❍	❍	❍
The physical sciences to engineering problems	❍	❍	❍	❍	❍
Computer tools and applications to engineering problems	❍	❍	❍	❍	❍
Life sciences to engineering problems	❍	❍	❍	❍	❍

11. <u>Defining Problems and Generating Design Solutions</u>. Please rate your ability to:

	Weak/ none	Fair	Good	Very good	Excellent
Define design problems and objectives clearly and precisely.	❍	❍	❍	❍	❍
Ask questions to understand what a client/customer really wants in a "product."	❍	❍	❍	❍	❍
Undertake a search (literature review, databases, benchmarking, reverse-engineering, etc.) before beginning team-based brain-storming.	❍	❍	❍	❍	❍
Take into account the design contexts and the constraints they may impose on each possible solution (social, cultural, economic, environmental, political, ethical, etc.).	❍	❍	❍	❍	❍
Generate and prioritize criteria for evaluating the quality of a solution.	❍	❍	❍	❍	❍
Brainstorm possible engineering solutions.	❍	❍	❍	❍	❍
Apply systems thinking in developing solutions to an engineering problem.	❍	❍	❍	❍	❍
Develop pictorial representations of possible designs (sketches, renderings, engineering drawings, etc.).	❍	❍	❍	❍	❍
Evaluate design solutions based on a specified set of criteria.	❍	❍	❍	❍	❍
Producing a product (prototype, program, simulation, etc.).	❍	❍	❍	❍	❍

Center for the Study of Higher Education

Instructions: In the following section, you will be asked to rate your skill level and abilities in a variety of areas. If you're unfamiliar with, or have had no experience with, any of these, select the "Weak/none" option.

12. Managing a Design Project. Please rate your ability to:

	Weak/none	Fair	Good	Very good	Excellent
Break down a design project into manageable components or tasks.	❍	❍	❍	❍	❍
Identify team members' strengths/weaknesses and distribute tasks and workload accordingly.	❍	❍	❍	❍	❍
Recognize when changes to the original understanding of the problem may be necessary.	❍	❍	❍	❍	❍
Monitor the design process to ensure goals are being met.	❍	❍	❍	❍	❍
Put aside differences within a design team to get the work done.	❍	❍	❍	❍	❍

13. Engineering Contexts. Please rate your:

	Weak/none	Fair	Good	Very good	Excellent
Knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to an engineering problem.	❍	❍	❍	❍	❍
Knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit.	❍	❍	❍	❍	❍
Ability to use what you know about different cultures, social values, or political systems in developing engineering solutions.	❍	❍	❍	❍	❍
Ability to recognize how different contexts can change a solution	❍	❍	❍	❍	❍

Center for the Study of Higher Education

Instructions: In the following section, you will be asked to rate your skill level and abilities in a variety of areas. If you're unfamiliar with, or have had no experience with, any of these, select the "Weak/none" option.

14. Communication. Please rate your ability to:

	Weak/none	Fair	Good	Very good	Excellent
Write a well-organized, coherent report.	❍	❍	❍	❍	❍
Make effective audiovisual presentations.	❍	❍	❍	❍	❍
Construct tables or graphs to communicate a solution.	❍	❍	❍	❍	❍
Communicate effectively with clients, teammates, and supervisors.	❍	❍	❍	❍	❍
Communicate effectively with *non-technical* audiences.	❍	❍	❍	❍	❍
Communicate effectively with people from different cultures or countries.	❍	❍	❍	❍	❍

15. Teamwork. Please rate your ability to:

	Weak/none	Fair	Good	Very good	Excellent
Work with others to accomplish group goals.	❍	❍	❍	❍	❍
Work in teams of people with a variety of skills and backgrounds.	❍	❍	❍	❍	❍
Work in teams where knowledge and ideas from multiple engineering fields must be applied.	❍	❍	❍	❍	❍
Work in teams that include people from fields *outside engineering.*	❍	❍	❍	❍	❍

16. Leadership. Please rate your ability to:

	Weak/none	Fair	Good	Very good	Excellent
Help your group or organization work through periods when ideas are too many or too few.	❍	❍	❍	❍	❍
Develop a plan to accomplish a group or organization's goals.	❍	❍	❍	❍	❍
Take responsibility for group's or organization's performance.	❍	❍	❍	❍	❍
Motivate people to do the work that needs to be done.	❍	❍	❍	❍	❍

PENNSTATE 1855

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Instructions: **Indicate your level of agreement with the following statements.**

17. Interdisciplinary Knowledge and Skills. Do you agree or disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I value reading about topics outside of engineering (history, business, politics, the cultures of other parts of the world, etc.).	❍	❍	❍	❍	❍
I enjoy thinking about how different fields approach the same problem in different ways.	❍	❍	❍	❍	❍
Not all engineering problems have purely technical solutions.	❍	❍	❍	❍	❍
In solving engineering problems I often seek information from experts in other academic fields.	❍	❍	❍	❍	❍
Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.	❍	❍	❍	❍	❍
I see connections between ideas in engineering and ideas in the humanities and social sciences.	❍	❍	❍	❍	❍
I can take ideas from outside engineering and synthesize them in ways that help me better understand or explain a problem.	❍	❍	❍	❍	❍
I can use what I have learned in one field in another setting or to solve a new problem.	❍	❍	❍	❍	❍

18. Recognizing Perspectives. Do you agree or disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I often step back and reflect on what I am thinking to determine whether I might be missing something.	❍	❍	❍	❍	❍
I frequently stop to think about where I might be going wrong or right with a problem solution.	❍	❍	❍	❍	❍
If asked, I could identify the *kinds of knowledge and ideas* that are distinctive to different fields of study (chemistry, psychology, literature, etc.).	❍	❍	❍	❍	❍
I recognize the kinds of evidence that different fields of study rely on.	❍	❍	❍	❍	❍
I'm good at figuring out what experts in different fields have missed in explaining a problem or proposing a solution.	❍	❍	❍	❍	❍
I usually know when my own biases are getting in the way of my understanding of a problem or finding a solution.	❍	❍	❍	❍	❍

Center for the Study of Higher Education

PROGRAM EMPHASES

Instructions: Overall, how much have the courses you've taken in your engineering program emphasized each of the following:

20. Topics in Engineering

	Little/no emphasis	Slight	Moderate	Strong	Very strong
Ethical issues in engineering practice.	❍	❍	❍	❍	❍
The importance of life-long learning.	❍	❍	❍	❍	❍
Examining my beliefs and values and how they affect my ethical decisions.	❍	❍	❍	❍	❍
The value of gender, racial/ethnic, or cultural diversity in engineering.	❍	❍	❍	❍	❍
Creativity and innovation.	❍	❍	❍	❍	❍
Current workforce and economic trends (globalization, outsourcing, etc.).	❍	❍	❍	❍	❍
Emerging engineering technologies.	❍	❍	❍	❍	❍
How theories are used in engineering practice.	❍	❍	❍	❍	❍

21. Professional Skills

	Little/no emphasis	Slight	Moderate	Strong	Very strong
Professional skills (knowing codes and standards, being on time, meeting deadlines, etc.)	❍	❍	❍	❍	❍
Written and oral communication skills	❍	❍	❍	❍	❍
Leadership skills	❍	❍	❍	❍	❍
Working effectively in teams	❍	❍	❍	❍	❍
Project management skills (budgeting, monitoring progress, managing people, etc.)	❍	❍	❍	❍	❍

Center for the Study of Higher Education

Instructions: Overall, how much have the courses you've taken in your engineering program emphasized each of the following:

22. Problem Solving

	Little/no emphasis	Slight	Moderate	Strong	Very strong
Understanding how an engineering solution can be shaped by environmental, cultural, economic, and other considerations	❍	❍	❍	❍	❍
Understanding how non-engineering fields can help solve engineering problems	❍	❍	❍	❍	❍
Systems thinking	❍	❍	❍	❍	❍
Applying knowledge from other fields to solve an engineering problem	❍	❍	❍	❍	❍
Defining a design problem	❍	❍	❍	❍	❍
Generating and evaluating ideas about how to solve an engineering problem	❍	❍	❍	❍	❍

23. Since starting your engineering program, approximately how many months have you spent participating in each of the following:

Undergraduate research activities _______

Engineering internship _______

An engineering cooperative education experience ______

24. How important to your academic success in engineering are the services of a learning/tutoring center at your college?

❍ Not at all important
❍ Slightly important
❍ Moderately important
❍ Very important
❍ Extremely important

25. Approximately how many courses have you completed to date in the following fields:

Humanities (history, art, literature, foreign languages, etc.) _______

Social sciences (economics, sociology, political science, psychology, etc.) _______

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CLASSROOM EXPERIENCES

26. In your engineering courses, how often have your instructors:

	Never	Rarely	Sometimes	Often	Very often
Set clear expectations for performance	❍	❍	❍	❍	❍
Only covered what was in the textbook	❍	❍	❍	❍	❍
Conveyed the same material in multiple ways (in writing, diagrams, orally, etc.)	❍	❍	❍	❍	❍
Explained new concepts by linking them to what students already know	❍	❍	❍	❍	❍
Used examples, cases, or metaphors to explain concepts	❍	❍	❍	❍	❍
Answered questions or gone over material until students "got it"	❍	❍	❍	❍	❍
Provided guidance or training in how to work effectively in groups	❍	❍	❍	❍	❍
Lectured	❍	❍	❍	❍	❍
Provided hands-on activities and/or assignments	❍	❍	❍	❍	❍
Used in-class, small group learning	❍	❍	❍	❍	❍
Assigned group projects	❍	❍	❍	❍	❍

27. In your engineering courses, how often do:

	Never	Rarely	Sometimes	Often	Very often
Male students treat other male students better than female students	❍	❍	❍	❍	❍
White students treat other white students better than non-white students	❍	❍	❍	❍	❍
When working in groups, male students treat other male students better than female students	❍	❍	❍	❍	❍
When working in groups, white students treat other white students better than non-white students.	❍	❍	❍	❍	❍
Instructors treat male students better than female students	❍	❍	❍	❍	❍
Instructors treat white students better than non-white students	❍	❍	❍	❍	❍
Women students get treated better than male students	❍	❍	❍	❍	❍
Minority students get treated better than white students	❍	❍	❍	❍	❍

28. Do you agree or disagree with the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Some engineering students use offensive words, behaviors, or gestures directed at students because of their gender.	❍	❍	❍	❍	❍
Some engineering students use offensive words, behaviors, or gestures directed at students because of their race/ethnicity.	❍	❍	❍	❍	❍
My gender has or will influence my choice of engineering field.	❍	❍	❍	❍	❍
My gender will negatively influence my engineering career.	❍	❍	❍	❍	❍
My race/ethnicity has or will influence my choice of engineering field.	❍	❍	❍	❍	❍
My race/ethnicity will negatively influence my engineering career.	❍	❍	❍	❍	❍

EXTRACURRICULAR EXPERIENCES

29. <u>During the past year</u>, how active have you been in:

	Not active	Slightly active (attend occasionally)	Moderately active (attend regularly)	Highly active (participate in most activities)	Extremely active (hold a leadership post)
An engineering club or student chapter of a professional society (IEEE, ASME, ASCE, etc.)	❍	❍	❍	❍	❍
Other engineering-related clubs or programs for women and/or minority students (e.g. NSBE, SHPE, SWE, WISE, etc.)	❍	❍	❍	❍	❍
Other clubs or activities (hobbies, civic or church organizations, campus publications, student government, Greek life, sports, etc.)	❍	❍	❍	❍	❍

30. <u>During the past year</u>, about how many weeks did you spend participating in:

Study abroad or on an international, school-related tour _______

Humanitarian engineering projects (Engineers without Borders, etc.) _______

Non-engineering related community service or volunteer work _______

Student design project(s)/competition(s) beyond class requirements _______

31. <u>During the past six months</u>, about how many times did you meet outside of class with a faculty member to: (count only <u>conversations of 10 minutes or more</u>)

Discuss academic or course-related matters _______

Ask about careers or get professional advice _______

Talk informally _______

COMMUNITY COLLEGE TRANSFER EXPERIENCES

32. Did you complete your associate's degree before transferring to your four-year college?

❍ Yes
❍ No

33. Do you agree or disagree with the statement: "My community or two-year college advisor was very knowledgeable of the transfer process?"

❍ Strongly disagree
❍ Disagree
❍ Neither agree nor disagree
❍ Agree
❍ Strongly agree

34. How many courses did you complete at a community or two-year college in the following areas?

Calculus _______
Chemistry _______
Physics _______
Computer programming _______
Introduction or overview of engineering _______
Other engineering courses _______

35. How well did your community or two-year college <u>math</u> courses prepare you for your engineering major?

❍ Not at all
❍ Slightly
❍ Moderately
❍ Well
❍ Very well

36. How does the community or two-year college you transferred from compare to the school you're now attending in:

	Very poorly	Poorly	About the same	Better	Much better
Quality of teaching	❍	❍	❍	❍	❍
Availability of instructors outside of class	❍	❍	❍	❍	❍
Availability of staff and advisors	❍	❍	❍	❍	❍
Scheduling flexibility (courses offered when you need/want them)	❍	❍	❍	❍	❍
Academic support services	❍	❍	❍	❍	❍
Willingness to help students whose first language is not English	❍	❍	❍	❍	❍

ADDITIONAL INFORMATION

37. <u>In a typical week</u>, how many hours do you spend:

Preparing for class (studying, doing homework or lab work, and other academic activities) ________

Working for pay ________

Meeting family responsibilities(care of siblings, children, other family members) ________

Commuting to and from school or work ________

38. <u>Three years after you graduate</u>, how likely is it that you will:

	Definitely won't	Probably won't	Not sure	Probably will	Definitely will
Be self-employed in engineering	❍	❍	❍	❍	❍
Be a practicing engineer in industry, government, or non-profit organization	❍	❍	❍	❍	❍
Work in engineering management or sales	❍	❍	❍	❍	❍
Work outside engineering	❍	❍	❍	❍	❍
Be in graduate school preparing to become an engineering faculty member	❍	❍	❍	❍	❍
Be in graduate school in engineering preparing to work in industry, government, or non-profit organization	❍	❍	❍	❍	❍
Be in graduate school in a field other than engineering (business, medicine, law, etc.)	❍	❍	❍	❍	❍

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39. Have you been enrolled at your current institution primarily:
- ❍ Full-time
- ❍ Part-time

40. Is English your native language?
- ❍ Yes
- ❍ No

41. What was the first math course you took after completing high school?
- ❍ Math required prior to algebra
- ❍ Another math course (algebra, geometry, trigonometry, pre-calculus, etc.)
- ❍ Calculus or above

42. Since enrolling in college, how many years have you lived:

In a general residence hall _______

In a residence area specifically for majors in engineering, science, or math _______

In a fraternity or sorority _______

With parents, spouse/domestic partner, or other relatives _______

Off-campus in private quarters _______

43. Have you taken the Fundamentals of Engineering (FE) exam?
- ❍ No
- ❍ Yes in (most recent year) ________

44. Did you pass?
- ❍ Yes
- ❍ No
- ❍ Not applicable

Thank you very much for your participation! The responses you have given us will help engineering programs nationwide improve their educational practices. If you have any questions about this study please contact us at e2020@psu.edu. You can also follow the progress of this study at http://www.ed.psu.edu/educ/e2020/p2p.

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