

America's Overlooked Engineers:

Community Colleges and
Diversity in Engineering Education

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Foreword

In 2004, the National Academy of Engineering published *Educating the Engineer of 2020: Visions of Engineering in the New Century*. The report foresees a world of dynamic technological change requiring future engineers to have, in addition to strong analytical skills, an understanding of complex societal, global, and professional contexts; creativity and practical ingenuity; communications, management, and leadership skills; high ethical standards and professionalism; and agility, resilience, and interdisciplinary thinking and teamwork. The Academy's report inspired "The Engineer of 2020" project, a National Science Foundation-supported set of interrelated studies of engineering education. *Prototype to Production: Conditions and Processes for Educating the Engineer of 2020* (NSF-EEC-0550608), or "P2P," sought to benchmark undergraduate engineering education in the U.S. against the attributes the National Academy report believes future engineers will need in order to be effective. NAE's report also called attention to the rapid population growth both globally and among minorities in the U.S. Such changes, the report stressed, have "major implications for the future of engineering, a profession where minorities and women remain underrepresented" (p. 4). Because of the urgency of increasing the representation of historically underrepresented groups in engineering schools and in the workforce expressed by the Academy and numerous others, and given growing calls to capitalize on the nation's community colleges as potentially fruitful grounds for recruiting diverse students to engineering, the Engineer of 2020 project included a survey of community college students planning to transfer into a four-year engineering program.¹ This summary of findings from the Engineer of 2020 project surveys is intended to assist engineering deans, department heads, faculty members, associations and professional societies, industry, and public policy makers in their efforts to diversifying engineering education and better prepare engineers to function effectively in the near- and long-term future.

Acknowledgements

We are indebted to many individuals² and organizations, including the 46 community college and four-year participating institutions (see back cover) and their engineering students, faculty members, program chairs, and associate deans of the four-year programs who also shared their time, ideas, experiences, and views with us. We would also like to thank the engineering faculty, staff, and students of Penn State's University Park and Altoona campuses, City College of New York, Hostos Community College, and Borough of Manhattan College for their assistance in developing instruments for our studies. Without their generosity, the Engineer of 2020 project studies and this report would not exist. Finally, we are deeply grateful to the National Science Foundation, particularly to Sue Kemnitzer, Myles Boylan, and Russ Pimmel for their support throughout the Engineer of 2020 projects, and to Alan Cheville for his encouragement and support to produce this report.

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¹ A brief summary of the studies' samples and methods is given at the end of this report.

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America's Overlooked Engineers: Community Colleges and Diversity in Engineering Education

More than a decade ago, the U.S. Department of Defense (2001) identified development of a more diverse STEM workforce as a national security issue for the 21st century. Two National Academy of Engineering reports (2004, 2005) and numerous others have since echoed the warning, forecasting that if American engineering is to remain globally competitive, undergraduate engineering programs must more closely reflect America's racial/ethnic, gender, socioeconomic, and cultural diversity. Charles Vest, then president of the National Academy of Engineering, was more graphic and urgent: "Projecting forward, we have a workforce train wreck. We need to take action now to avoid it" (in Didion, Fortenberry, & Cady, 2012, p. v).

The problem is not new. Over the past half-century, the percentage of engineering bachelor's degrees awarded to women rose steadily, if weakly, from 0.4% in 1966 to a high of 20.9% in 2002. By 2008, however, that percentage had slipped to 18.5% (National Science Foundation, 2011, Table 11). Minority students have fared even worse. From 1997 to 2006, the percentage of historically underrepresented minority students earning engineering bachelor's degrees rose almost imperceptibly from 12.0% to 12.4%. The percentage of African Americans actually declined from 4.9% to 4.7%, while Hispanic Americans grew from 6.6% to 7.2% (National Science Foundation, 2009, Table 4).

Because of the rich diversity of their student populations, America's community colleges are slowly attracting attention as potential reservoirs of the kinds of diverse people and diverse thinking needed in a creative and competitive engineering workforce. Adelman (1998), Chubin, May, and Babco (2005), Mooney and Foley (2011), the National Academy of Engineering (2004, 2005), and the National Research Council (Mattis & Sislin, 2005) have all urged that greater attention be given to community colleges as potential sources of diverse future engineers, and the research supports their arguments. Community colleges already have a strong presence in engineering education. Using several sources,⁴ we estimate that "non-incidentally" community college transfer students earn between 12% and 17% of the engineering bachelor's degrees awarded each year. This report provides a portrait of these students – America's "overlooked engineers," who they are, what their college experiences are like, and how their engineering skills compare with those of students who began their engineering studies at a four-year institution.

Who are these "overlooked engineers"?

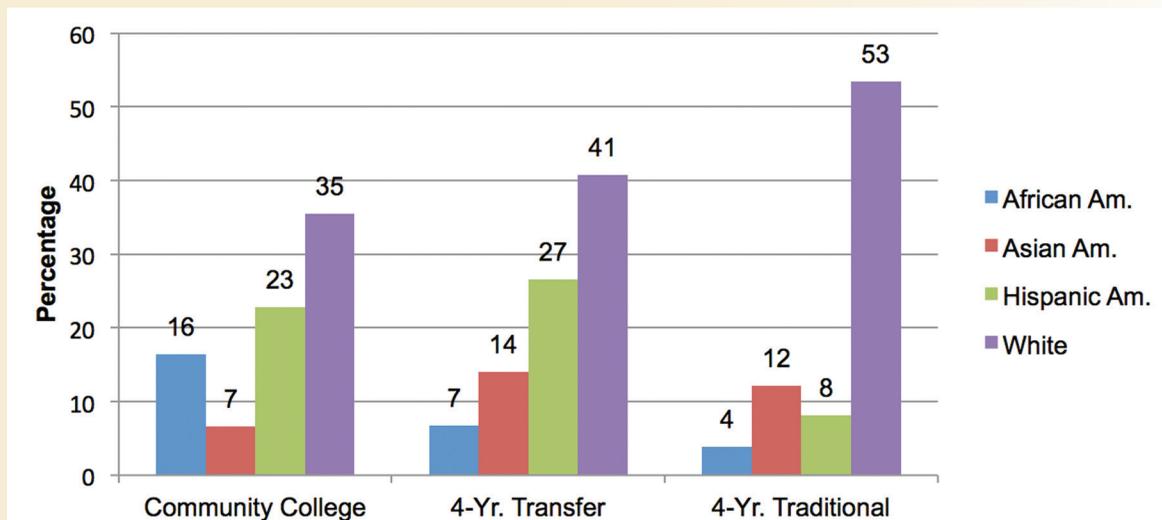
To sharpen the portrait's focus, we contrast three separate groups: 1,245 community college students who in spring, 2009 indicated they "probably" or "definitely" would transfer to a four-year school to complete a bachelor's degree in engineering; 846 students who started in a community college and then transferred into a four-year engineering program (hereafter, "transfers") at one of the 31 four-year schools we studied; and 4,085 students who began their engineering studies at those same 31 institutions (hereafter, "traditional" students).

When they started their college careers, the community college and transfer students we studied differed in a number of ways from those in our sample of traditional students. Both community college and transfer students are less likely to be women (14% and 13%, respectively, vs. 21% in the traditional group) and more likely to come from an historically underrepresented group (i.e., African Americans or Hispanic/Latino Americans;⁵ see Figure 1).

⁴ Adelman (1998), National Science Foundation (2012), Lattuca, Terenzini, and Volkwein (2006), and Engineer of 2020 datasets.

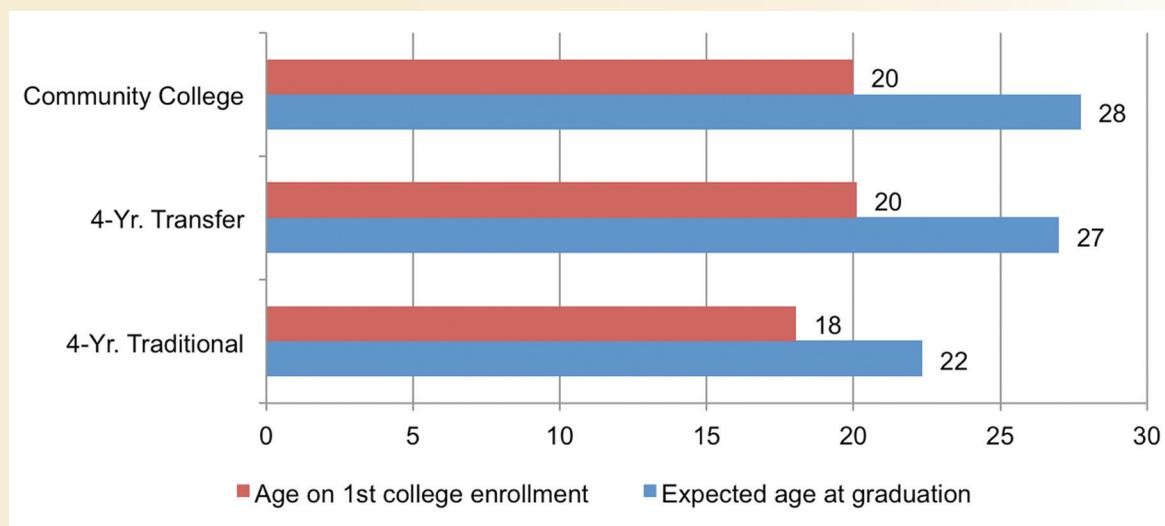
⁵ Consistent with National Center for Education Statistics' practice (Aud, Fox, & KewalRamani, 2010), we have shortened "Hispanic/Latino" to "Hispanic American." American Indian/Alaskan Native students are not included in our analyses because of their small number (less than 1%) in each of our three samples.

Figure 1. Community college, transfer, and traditional engineering students by race/ethnicity.



In our non-random sample, nearly 40% of these 15 community colleges' students are from underrepresented minority groups, and that one-third of those who transferred to a four-year program are African American or Hispanic American underscores the potential of community colleges as a viable pathway to bachelor's degrees in engineering. Although every community college is not demographically diverse, and not all of them offer an engineering transfer program, the community colleges in general are a potential resource for diversifying engine programs and workforce, particularly those in large suburban and urban areas (all of our 15 participating schools are public, and 12 are in suburban or urban locations). Judging from our purposive (non-random) sample of community colleges, the potential for recruiting Hispanic engineering students from community colleges appears stronger than for African Americans.

Figure 2. Mean age of community college, transfer, and traditional students when first enrolling in college and at the time of expected bachelor's degree completion.

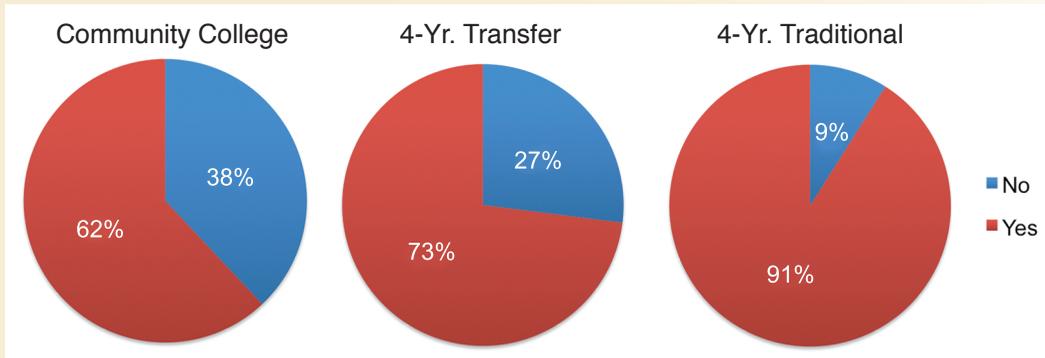


Some of the differences between community college and transfer students and their traditional counterparts constitute obstacles to the successful completion of college. As shown in Figure 2, community college and transfer students are, on average, about two years older than their traditional counterparts when they begin college.⁶ They also expect to take five to six years longer to complete their bachelor's degrees. These differences are substantial (two to three standard deviations), suggesting that more students could be successful if delays in initial enrollment or in transferring to a four-year program and part-time enrollment could be reduced.

⁶Delayed college entry after high school (Horn, et al., 2005) or a delay of more than one year between community college and transfer to a four year program (Shapiro, et al., 2013) reduce a student's chances of completing a degree. See also Complete College America (2011).

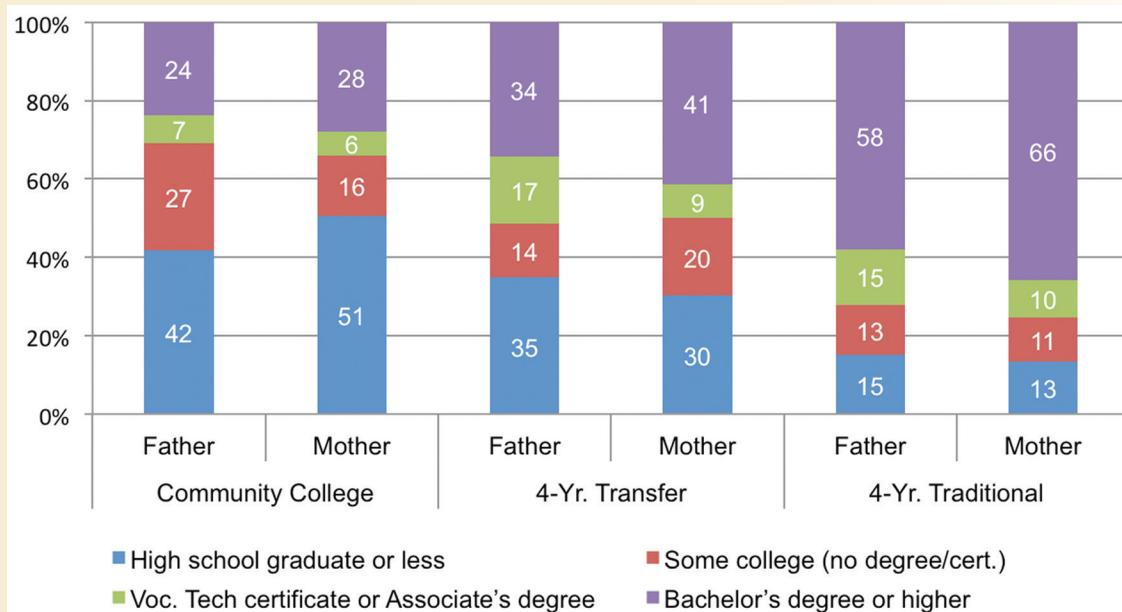
Community college and transfer students are also substantially less likely to be native-English speakers (Figure 3) and less likely to have parents with significant college experience (Figure 4). Two-thirds (67%) of the traditional students report that their mother earned a bachelor's degree or higher, compared to 40% of the transfers and 28% of the community college students. Fathers' educational attainment patterns across these groups resemble those of the mothers. African American (particularly) and Hispanic American community college and transfer students are also more likely than traditional students to report having family members or relatives financially dependent on them.

Figure 3. English as first language among community college, transfer, and traditional students.



Community college and transfer students confront other challenges to educational success. Compared with their traditional counterparts, they begin their college careers with weaker academic preparation.⁷ According to their self-reported high-school grades, community college students, on average, performed in the “B-minus” to “B” range, transfer students in the “B” to “A-minus” range, and traditional students in the “A-minus” to “A” range.

Figure 4. Educational attainment of parents of community college, transfer, and traditional students.



⁷ SAT/ACT score comparisons are not reported since relatively few community college students take those tests.

Some readers may interpret these group profiles as suggesting that community colleges may not, after all, be particularly rich or cost-effective grounds for recruiting minority engineering students. Despite the personal and academic challenges community college students in general face, the past 35 years of research consistently show that

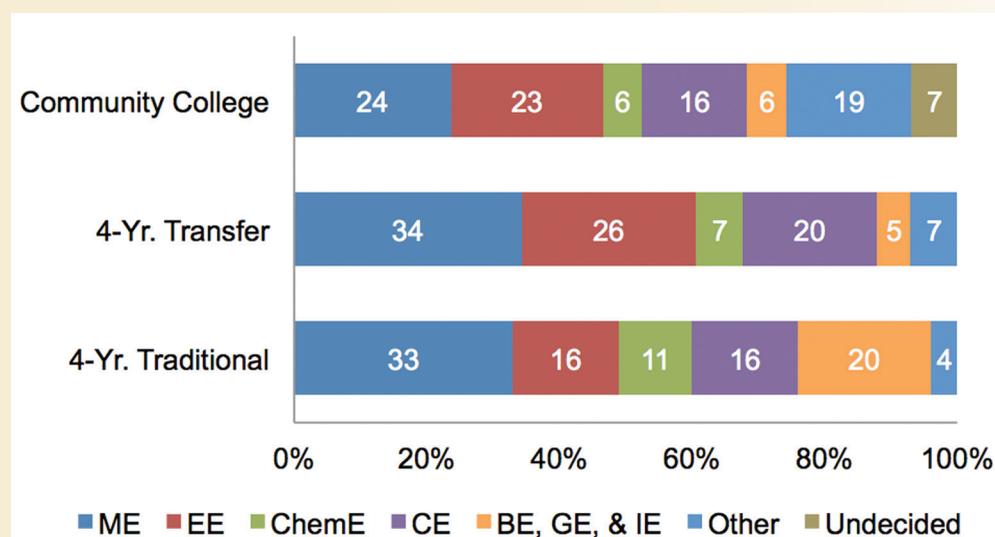
Community college and transfer students face non-trivial challenges arising from delayed college entry; relatively weaker precollege academic backgrounds and achievement levels, particularly in math; employment and family obligations; limited financial resources, and a native language that may not be English.

what happens to students after enrollment is more strongly related to subsequent success than the precollege characteristics they bring to college (Pascarella & Terenzini, 2005). We turn now to some of those “during-college” experiences that shape student success.

College Experiences: Academic

Figure 5 arrays the distributions of the major fields community college students are planning and four-year students have declared. The relatively larger fields of mechanical and electrical engineering draw the largest numbers in each group, together accounting for nearly half of all community college and transfer students and 60% of the traditional students. Chemical, general and bio-/biomedical engineering, however, attract less attention from community college students, perhaps because they have never heard of those fields, their pre-engineering programs do not have the resources to offer those programs, or perhaps both. The finding implies that engineering societies, associations, and industry as well as four-year institutions, might do more to make students aware of these smaller-program options. In any event, four-year programs in these fields can probably anticipate more difficulty than larger ones in recruiting underrepresented students.

Figure 5. Distributions of students' planned (community college) and declared major fields.*



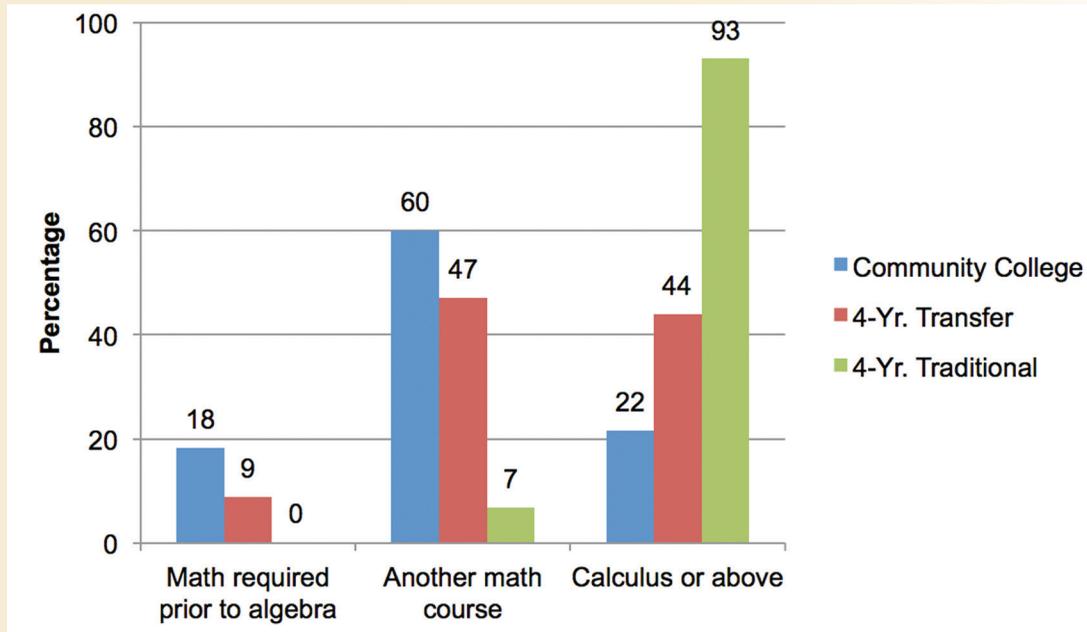
* CE = Civil, BE = Bio-/Biomedical, GE = General

Community college students' underdeveloped math skills constitute another significant challenge in capitalizing on the diversity in community colleges. Figure 6 contrasts the groups' levels of preparation based on the first math course students took after high school, and the differences across the groups are striking:

- More than half (56%) of the transfer and 78% of the community college students had to complete a lower-level math course before taking a college-level course in calculus or above.
- 30-35% of community college students across all racial/ethnic categories had repeated at least one math course.

- 44% of the transfers and nearly a quarter (22%) of the community college students, however, began their college math studies with calculus or something more advanced.
- Nearly 70% of the transfer students across class years reported their community college math courses had prepared them “well” or “very well” for their four-year engineering major.

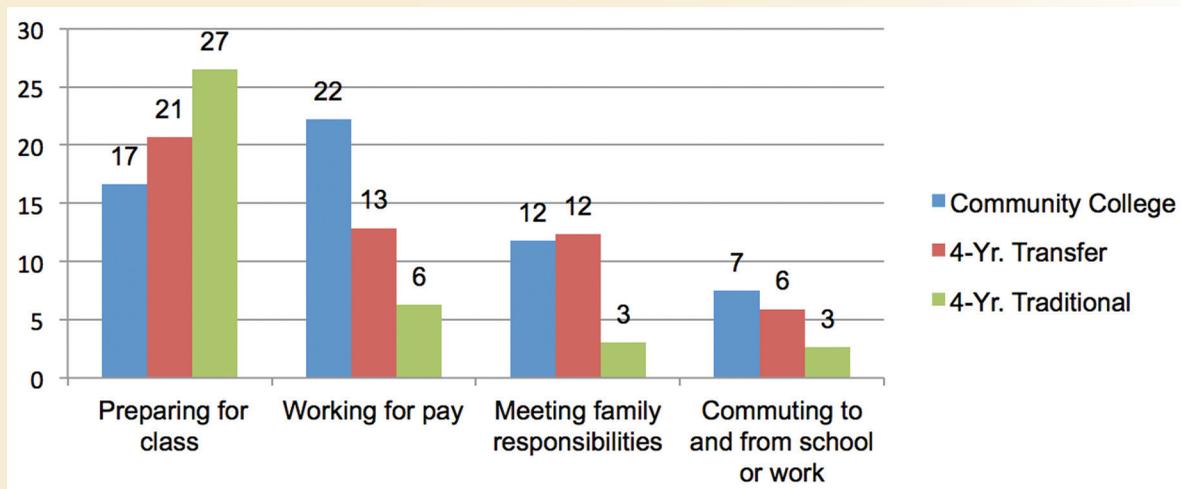
Figure 6. Students' first, post-high school math course.



Other College Experiences: Juggling Academic and Non-Academic Responsibilities

To get a glimpse into students' personal and collegiate lives, we asked all three groups how much time they spend in selected activities during a typical week (Figure 7). The differences are sometimes dramatic. Traditional engineering students spend an average of 27 hours per week preparing for class, six hours (29%) more than their transfer colleagues and 10 hours more than community college students. In that typical week, community college students also put in the equivalent of a full work-week (41 hours) in activities *other than* preparing for class. Transfer students are not far behind, spending 31 hours per week working, meeting family obligations, and commuting. Traditional students spend about 12 hours per week in those activities.

Figure 7. Mean hours-per-week spent in selected activities.



We note that the non-academic time demands facing community college and transfer students significantly reduces the time these students have to engage in the array of non-course activities that a substantial body of research indicates promotes academic and cognitive skill acquisition (Pascarella & Terenzini, 2005). In addition, analyses not shown here indicate that our transfer respondents are far less likely than their traditional peers to be involved in organizations or activities unrelated to engineering. They are also nearly 10 times less likely than their traditional classmates to live in on-campus housing (3.2% vs. 30.5%, respectively). On-campus residence has arguably the second largest impact on students' academic and intellectual development, second only to students' curricular-related experiences.

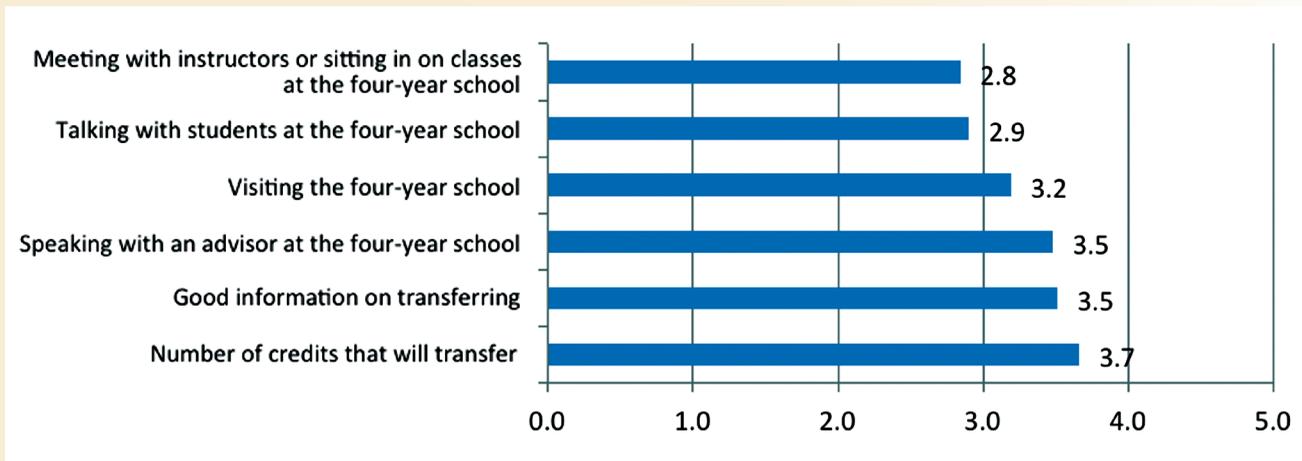
Community college students put in the equivalent of a full work-week in activities other than preparing for class.

Community College Students. Our community college respondents also reported on how they were learning about the transfer process:

- *Their top three information sources are web sites, their faculty advisor, and advising-center staff members.* Students rely on each of these sources, however, only “somewhat” to “moderately.” Hagedorn, et al. (2008) found early academic advising and enrollment in a transfer-focused community college curriculum was a major predictor of successful transfer. McArthur (2005) reached a similar conclusion. Hagedorn (2013) notes, however, that the student-to-advisor ratio, particularly in large urban community colleges, can exceed 2,000 to 1. Students' limited reliance on faculty and advising-center staff suggests they look elsewhere and rely on multiple sources for the information they get on transferring selecting courses that will meet transfer requirements.
- *African American and Hispanic American students are substantially more likely than Whites to rely on their official faculty advisor and advising-center staff.* This supplemental finding suggests the potential recruiting value of reaching individual faculty and advising-center staff members (rather than, say, deans, department heads, or advising-center directors) to identify potential transfers and introduce them to an institution's bachelor's degree programs.
- *Representatives of four-year engineering institutions play an important role.* Six-in-ten African Americans and about half of the Hispanic and White students report speaking at least once with a four-year school instructor or advisor.
- *Group presentations by four-year representatives are also popular.* About half of the African American and Hispanic students reported attending at least one presentation in the past year about transfer requirements and procedures by someone from a four-year college.

When asked about potential obstacles to transferring, respondents cited consistently only “cost of attendance” (in a list of 11 possible roadblocks). Although no minority group student mean exceeded 2.5 (or a “moderate” level of concern), cost was significantly and substantially of greater concern to African Americans and Hispanic students than to Whites. Asked what factors would be important in deciding whether to transfer, students reported that multiple factors are roughly about equally important (Figure 8). Five of the six factors related largely to information gathering.

Figure 8. Mean ratings* of important factors in community college students' decisions on whether to transfer.



*Where 1=not at all important, 2=slightly, 3=moderately, 4=very, and 5=extremely important.

Particularly noteworthy is that four of the six primary factors relate to some form of personal contact with representatives of a potential transfer institution. Each of the six factors, moreover, is significantly and substantially more important to African American and Hispanic students than to Whites. In two instances, the differences were uncommonly

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large (from one-half to three-quarters of a standard deviation): speaking with students and meeting with instructors, and sitting-in on a class at a four-year school. These findings suggest that any recruiting strategy should include personal contact between community college students and four-year students and faculty.

Outcomes: Learning

Given that differences outnumber the similarities among community college, transfer, and traditional students, one might reasonably ask what effects those differences have on students' engineering skill outcomes. The answers are surprising.

Community College Students. Because their math and science courses typically cover general knowledge and skills in these fields, we asked community college students to assess their skills in areas *relevant*, but not specific, to engineering.

Table 1. Community college students' mean self-reports of their engineering-related skill levels.*

Outcome	African American (n=116)	Asian American (n=56)	Hispanic American (n=313)	Caucasian (n=374)	Total (n=859)
Communication	3.48	3.74	3.58	3.77	3.65
Applying Math and Science	3.48	3.71	3.49	3.71	3.60
Problem Solving in Context	3.49	3.67	3.43	3.53	3.51
Teamwork and Leadership	3.92	3.93	3.93	3.79	3.87

*Where 1=weak/none, 2=fair, 3=good, 4=very good, and 5=excellent.

- As can be seen in Table 1: Overall, students' self-evaluations are generally similar across skill areas and groups.
- On average, community college students rate themselves highest in their *Teamwork and Leadership Skills* (the group means are all just below "very good").
- They rate themselves lowest in *Problem Solving in Context* skills (group means between 3.43 and 3.67, clustering about halfway between "good" and "very good.")
- Racial/ethnic group differences are statistically significant only in *Communication* (oral, visual, and written) and in *Applying Math and Science* skills (applying math, physical sciences, computer tools, and life sciences to "real world problems").
- White students rate themselves higher in both of those skills than do African American and Hispanic American students. Three of those four differences are "small" (effect sizes less than .30).⁸ The difference between White and African Americans' ratings (3.71 and 3.48, respectively) is slightly greater (effect size = .35).

⁸An effect size (Traditional mean minus Transfer mean divided by pooled standard deviation) reflects the magnitude of the difference between two means in standard deviation units. Cohen (1988) has given a widely (but certainly not universally) accepted set of characterizations, where an effect size of 0.2 to 0.3 is considered "small," 0.5 is "medium," and 0.8 to infinity is a "large" effect.

Four-year Transfer and Traditional Students.⁹ Table 2 summarizes senior-year traditional and senior-year transfer students' reports of their skills in each of nine areas.

Table 2. Comparisons^a of means of *senior-year* traditional and senior-year transfer students on measures of nine engineering skill learning outcomes.

Outcome ¹	Traditional (N=1993)	Transfer (N=294)	Effect Size ^b
Design Skills	3.78	3.57	.31***
Contextual Competence	3.47	3.36	.13*
Fundamental Skills	3.99	3.81	.28***
Teamwork Skills	4.01	3.84	.25***
Communication Skills	3.92	3.68	.36***
Leadership Skills	3.83	3.68	.19***
Interdisciplinary Skills	4.02	3.97	.11*
Reflective Behavior	4.05	4.13	-.14***

^a Differences in means evaluated using t-tests. Ratings based on a five-point scale, where 1 = weak/none, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.

^b An effect size (Traditional mean minus Transfer mean divided by pooled standard deviation) reflects the magnitude of the difference between two means in standard deviation units. Cohen (1988) has given a widely (but certainly not universally) accepted set of characterizations, where an effect size of 0.2 to 0.3 is considered "small," 0.5 is "medium," and 0.8 to infinity is a "large" effect.

*p < .05 **p < .01 ***p < .001

Several Table 2 findings are noteworthy:

- In eight of nine engineering skill areas, traditional students rate themselves higher than do transfer students. Transfers rate themselves slightly higher than traditional students in *Reflective Behavior Practice*.¹⁰ On all skills, ratings are in the "good" to "very good" range.
- Although eight of the nine differences are statistically significant, the magnitudes of all but one difference (see effect sizes) are at or below .30 and might be characterized as "small" (Cohen, 1988). Five of the nine effect-size differences are less than .20.
- Only in *Communication Skills*¹¹ is the effect size above .30 (.36, or in Cohen's "medium" range) and, thus, substantively noteworthy. Given the language-intensive items that constitute this scale, this difference might be attributed, at least in part, to the fact that for a higher proportion of traditional students, English is their native language (91% vs. 73% of the transfer students).
- The second largest difference is in students' reports of their *Design Skills* (effect size = .30, the boundary between "small" and "medium"). That transfer students rate themselves lower than traditional students may reflect the fact that community college students are less likely to have had a first-year or other lower-division design experience. Their engineering-relevant course work is more likely to have been in mathematics and the sciences. In the California Community College System, for example, the emphasis in transfer engineering programs is largely on calculus and physics, with "limited . . . actual engineering coursework" (Bahr, 2013).

Given the differences noted earlier in the two groups' precollege characteristics and their college experiences, one might reasonably ask why senior-year transfer and traditional students do not differ by more than they do in their self-reported, senior-year skills. One explanation may be that, compared to traditional students, transfers derive greater learning benefits from certain of their four-year college experiences. It may also be that transfer students are more mature, focused, or motivated than their traditional counterparts. Supplemental analyses indicate that, in our sample,

⁹ Four-year students evaluated themselves on a larger number and broader range of engineering-related skill items than did community college students. Items were aggregated into nine scales, each relating to a distinct category of engineering-relevant skills.

¹⁰ Ability to stop and think about where a problem solution might be going wrong or whether one might be missing something.

¹¹ Ability to make effective audio-visual presentations; construct explanatory tables/charts; write well-organized and coherent reports; communicate effectively with people from different cultures; and communicate effectively with clients, teammates, supervisors, and non-technical audiences.

sophomore-year traditional and transfer students differ more than do senior-year traditional and transfer students, suggesting that the earlier gap may close by students' senior year. Our data are not longitudinal, however, and one should be cautious in assuming that our senior-year respondents, when they were sophomores, were similar to our actual sophomores. Cross-sectional findings, however, are often similar to those of studies using longitudinal research designs (Pascarella & Terenzini, 1991, 2005).

The "closing-gap" hypothesis is supported by emerging evidence that, net of other factors, certain college experiences have greater impact on non-traditional than traditional students. For example, studying with peers, faculty use of active learning pedagogies, and more frequent student-faculty interaction appear to lead to greater gains in critical thinking among first-generation and historically underrepresented students than among traditional or White students (Terenzini, Springer, Pascarella, & Nora, 1995; Pascarella, Pierson, Wolniak, & Terenzini, 2004). Cruce, et al. (2006) found higher gains in cognitive ability, orientation to learning, and degree aspirations among students who enter college scoring below average on measures of those traits, as well as among historically underrepresented students, compared with students with more traditional student characteristics. Kuh, et al. (2008) found similar compensatory effects on first-year students' grades and persistence into the second year.

Conclusions and Implications for Engineering Education Policy and Practice

One solution to the persistent lack of diversity in undergraduate engineering and in the profession may lie with America's community colleges. The socioeconomic, racial/ethnic, and cultural heterogeneity of community college student bodies make those institutions potentially fruitful recruiting grounds for engineering schools seeking to increase the racial/ethnic and cultural diversity of their undergraduate programs. The findings reviewed in this report suggest several important implications for engineering education practice and policy:

- 1) **Community college students come to college with an array of personal and educational challenges.**
Compared to traditional students, community college and transfer students' backgrounds contain several "risk factors," including weaker academic preparation, delayed college entry, and significant non-academic demands on their time. These circumstances threaten these students' chances for success in both their community college and four-year engineering programs. Increasing the flow of community college students into four-year engineering programs will not be quick, easy, or cheap.
- 2) **Concluding from these differences that recruiting community college transfer students would be a poor investment would be a mistake.**
Community college transfers with bachelor's degrees are already well-represented in the engineering workforce. Among the engineering graduates from 2005-2007, 44% had had community college experience at some point before receiving their degree; 16% had enrolled after high school and before transferring into a four-year institution (National Science Foundation, 2012). Using data from Adelman (1998), Lattuca, et al. (2006), and our present database, we estimate that 12-17% of the bachelor's degree recipients transferred to those programs after non-incident enrollment in a community college (half with an A.S. degree in hand). A recent national study (Shapiro, et al., 2013) found that, of the students (in all fields) who had begun their postsecondary education in a community college and then transferred into a four-year program, 62% had earned a bachelor's degree or higher within six years. Moreover, the eight-year completion rate for students who started at a community college was six points higher than that of students who began at a four-year institution (71% and 65%, respectively).
- 3) **Community college students, the institutions they hope to attend, and the engineering community will confront at least three major challenges:**
 - a. *The time demands of activities unrelated to students' academic work.* Both during the community college years and after transferring into a four-year program, these students must balance employment and family obligations with their studies. Between a quarter and a third of community college students attend school part-time. In our study, the typical community college student spent 41 hours per week – the equivalent of a full workweek – in *non-academic* activities. The typical four-year transfer student invests 60% of an average 52-hour week in activities unrelated to coursework. These are hours lost to community college and transfer students for engaging in educationally productive activities, the benefits of which are more likely to accrue to their traditional student counterparts. Ways – financial and otherwise – must be found to permit community college students to invest more hours in their academic programs, even if they cannot attend full-time.

Given the hours community college students and transfer students spend in working, one solution might be to provide truly educational and meaningful "work-study" – engineering-related activities on campus (such as staffing labs or working on faculty research projects) that would reduce these students' reliance on off-campus

work, facilitating both income and skill development via a work setting that would also increase students' contact with engineering faculty members and students.

Alumni, industry, the professional societies, foundations, and governmental and other sources could be developed (and the support leveraged) to provide scholarships specifically for community college and transfer engineering students to reduce their dependence on employment. The same sources might provide funding for paid summer internships and "bridge" programs to facilitate students' transition and early academic involvement by reducing their need for summer employment.

- b. *Limited access to state and federal financial aid and other forms of support.* Part-time students confront non-trivial policy and procedural barriers to financial aid. Current restrictions on the availability, amounts, and types of financial aid for part-time students should be eased. Alternatives to loans for both full- and part-time low-income students will be particularly important since low-income and underrepresented students are debt-averse (Cunningham & Santiago, 2008; Ehrenberg, 1991; Paulsen & St. John, 2002). Current aid levels and eligibility requirements for part-time students should be reviewed and revised in ways that will permit community college students to enroll, if not full-time, then at least for more courses per semester than at present. In addition, all community college and transfer students should be made aware – through early financial aid counseling – that their financial choices can affect their academic success (King, 2002; McDonough & Calderone, 2006). For example, choosing to work rather than accept a loan is likely to reduce the time students might otherwise have for focusing on their academic activities. By investing more time per semester in their education, they are likely to shorten their time-to-degree; derive greater academic, intellectual, and personal benefits from their college experience; and enter the workforce at an earlier age.
- c. *The level of community college students' preparation in math.* Of the community college students in our study, 78% were required to complete a lower-level math course before taking college-level calculus. The math-preparation liability follows those who do transfer: for 56% of our transfer students, the first math course after high school was something below calculus.

These math-related findings have at least two obvious implications. First, adequate preparation in math during students' community college years (if not earlier) is critical for transferring and subsequent success in a four-year engineering program (Adelman, 1998; Hagedorn & DuBray, 2010). Second, ways should be found for community colleges and four-year institutions (and other groups) to work together to strengthen the math preparation sequence for pre-engineering students before and during their community college years.

One possibility might be partnerships between four-year institutions and near-by community colleges to capitalize on mathematics courses available on-line (whether offered by the partner or another four-year institution). A potentially more beneficial approach would be to involve upper-division and graduate engineering students in teaching or tutoring community college students in math either on-line or in-person. Industry, professional society, and other external funds could support these undergraduate and graduate students and the tutoring program.

Such arrangements are likely to benefit all parties. Community colleges could enhance their capabilities for delivering math courses in greater number, variety, and credit-generating volume. Upper-division and graduate students planning faculty careers would have opportunities to develop their course-planning, instructional, and classroom management skills. Four-year programs would be in position to identify and recruit promising community college students, assist them through the transfer and transition processes, and increase their likelihood of success in transferring and graduating. Current upper-division transfers are particularly likely to support such programs.

4) **Recruiting community college students effectively will require more than articulation agreements.**

Our "overlooked engineers" were concerned about the number of their credits that will transfer to a four-year program. Thus, maximizing the alignment of the content and credit-value of community college and four-year institution courses, as well as early and transfer-focused academic advising, will be vital to avoiding the loss of hard-earned credits, wasting personal and institutional financial resources, and extending students' time-to-degree. The evidence strongly indicates, however, that articulation agreements, although necessary, are likely to be insufficient. Comprehensive strategies will be needed. Our community college students were relying (about equally) on multiple sources of information. Personal contact with four-year students and faculty, however, appear to be particularly important to African American and Hispanic American students. Mattis and Sislin (2005) provide an extensive discussion of other potential steps, as do Packard, Gagnon, and Senas (2012). Complete College America (2011) recommends succinct steps for state and national policy makers. It seems clear that effective transfer recruiting will require community college and four-year institutions – supported by industry, professional engineering societies and organizations, and state and federal governments – to adopt a variety of approaches. In our view, the greater the integration and coordination in a coherent, comprehensive plan and delivery system, the greater the likelihood of transfer student academic success and graduation.

The evidence from our studies indicates with some clarity that community colleges are, indeed, a promising potential source of “overlooked engineers,” and recruiting and supporting these students could begin to help redress the racial/ethnic imbalance in engineering education.

Chubin, et al. (2005) suggest that, rather than viewing diversity as primarily an issue of morality or fairness, “Better that we think of diversity as an asset, an enabler that makes teams more creative, solutions more feasible, products more usable, and citizens more knowledgeable. Diversity arguably makes any profession, but especially science and engineering, more competent” (pp. 73-74). The evidence from our studies indicates with some clarity that community colleges are, indeed, a promising potential source of “overlooked engineers,” and recruiting and supporting these students could begin to help redress the racial/ethnic imbalance in engineering education. Moreover, our research indicates that goal can be achieved without compromising the quality of engineering graduates. Students beginning their college careers in a community college differ from traditional engineering students in a number of ways, but by their senior year, transfer and traditional students rate their engineering skills at comparable levels. Moreover, we found no evidence to suggest that their on-the-job performance is any less than that of their traditional peers. Capitalizing on the diversity in the America’s community college student population, however, will require addressing community college and transfer students’ personal and academic challenges, and that will require changes in how colleges of engineering currently recruit, enroll, and support transfer students. Four-year institutions, however, cannot do it alone. The shared responsibility and involvement of two- and four-year institutions, industry, engineering professional societies and associations, and state and federal governments will be needed. As noted, the evidence clearly indicates that, once the transfer to a four-year program has been successfully made, these “overlooked engineers” can – indeed, are likely to – be academically successful.

References

- Adelman, C. (1998). *Women and men of the engineering path: A model for analyses of undergraduate careers*. Washington, DC: U.S. Department of Education.
- Aud, S., Fox, M. A., & KewalRamani, A. (2010, July). *Status and trends in the education of racial and ethnic groups* (NCES No. 2010-015). Washington, DC: National Center for Education Statistics.
- Bahr, P. R. (2013). Personal e-mail, April 29, 2013.
- Chubin, D. E., May, G. S., & Babco, E. L. (2005). Diversifying the engineering workforce. *Journal of Engineering Education*, 94(1), 73-86.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.
- Complete College America (2011). *Time is the enemy*. Washington, DC: Author.
- Cruce, T. M., Wolniak, G. C., Seifert, T. A., & Pascarella, E. T. (2006). Impacts of good practices on cognitive development, learning orientations, and graduate degree plans during the first year of college. *Journal of College Student Development*, 47(4), 365-383.
- Cunningham, A. F., & Santiago, D. A. (2008). *Student aversion to borrowing: Who borrows and who doesn't*. Washington, DC: Institute for Higher Education Policy and Excellence in Education.
- Didion, C., Fortenberry, N. L., & Cady, E., Rapporteurs. (2012). *Colloquy on minority males in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.
- Ehrenberg, R. G. (1991). Decisions to undertake and complete doctoral study and choices of sector or employment. In C. T. Clotfelter, R. G. Ehrenberg, M. Getz, & J. J. Siegfried (Eds.), *Economic challenges in higher education* (pp. 174-210). Chicago, IL: University of Chicago Press.
- Kuh, G. D., Cruce, T. M., Shoup, R., Kinzie, J., & Gonyea, R. M. (2008). Unmasking the effects of student engagement on first-Year college grades and persistence. *Journal of Higher Education*, 79(5), 540-563.
- Hagedorn, L. S. (2013). Personal communication, July 22, 2013.
- Hagedorn, L. S., Cypers, S., & Lester, J. (2008) Looking in the rearview mirror: A retrospective look at the factors affecting transfer for urban community college students. *Community College Journal of Research and Practice* 32(9), 643-664.
- Hagedorn, L. S., & DuBray, D. (2010). Math and science success and nonsuccess: Journeys within the community college. *Journal of women and minorities in science and engineering*, 16(1), 31-50.
- Horn, L., Cataldi, E. F., & Sikora, A. (2005). Waiting to attend college: Undergraduates who delay their postsecondary enrollment. NCES 2005-152. Washington, DC: National Center for Education Statistics.
- King, J. E. (2002). *Crucial choices: How students' financial decisions affect their academic success*. Washington, DC: American Council on Education, Center for Policy Analysis.
- Kuh, G. D., Cruce, T. M. Shoup, R., Kinzie, J., & Gonyea, R. M. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *Journal of Higher Education*, 79, 540-563.
- Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). *Engineering change: A study of the impact of EC2000, Final report*. Baltimore, MD: ABET, Inc.
- Mattis, M. C., & Sislin, J. (Eds.). (2005). *Enhancing the community college pathway to engineering careers*. Washington, DC: National Academies Press.

- McArthur, R. (2005). Faculty based advising: An important factor in community college retention. *Community College Review*, 32(4), 1.
- McDonough, P. M., & Calderone, S. (2006). The meaning of money: Perpetual differences between college counselors and low-income families about college costs and financial aid. *American Behavioral Scientist*, 49(12), 1703-1718.
- Mooney, G. M., & Foley, D. J. (2011, July). Community colleges: Playing an important role in the education of science, engineering, and health graduates. NSF 11-317. Alexandria, VA: National Science Foundation, National Center for Science and Engineering Statistics.
- National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academies Press.
- National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.
- National Science Foundation, Division of Science Resources Statistics. (2009). Science and Engineering Degrees, by Race/Ethnicity: 1997-2006. NSF 10-30. Arlington, VA.
- National Science Foundation. (2011). S&E degrees: 1966-2008, detailed statistical tables. Division of Science Resources Statistics, NSF 11-316. Arlington, VA.
- National Science Foundation. (2012). Characteristics of Recent Science and Engineering Graduates: 2008. Detailed Statistical Tables, NSF 12-238. Arlington, VA.
- Packard, B. W., Gagnon, J. L., & Senas, A. J. (2012). Navigating community college transfer in science, technical, engineering, and mathematics fields. *Community College Journal of Research and Practice*, 36, 670-683.
- Pascarella, E. T., Pierson, C. T., Wolniak, G. C., & Terenzini, P. T. (2004). First-generation college students: Additional evidence on college experiences and outcomes. *Journal of Higher Education*, 75, 249-284.
- Pascarella, E. T., & Terenzini, P. T. (1991). *How college affects students: Findings and insights from twenty years of research*. San Francisco: Jossey-Bass.
- Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students (Vol. 2): A third decade of research*. San Francisco: Jossey-Bass.
- Paulsen, M. B., & St. John, E. P. (2002). Social class and college costs: Examining the financial nexus between college choice and persistence. *Journal of Higher Education*, 73, 189-236.
- Shapiro, D., Dundar, A., Ziskin, M., Chiang, Y., Chen, J., Harrell, A., & Torres, V. (2013). *Baccalaureate attainment: A national view of the postsecondary outcomes of students who transfer from two-year to four-year institutions*. Herndon, VA: National Student Clearinghouse Research Center.
- Terenzini, P. T., Springer, L., Pascarella, E. T., & Nora, A. (1995). Influences affecting the development of students' critical thinking skills. *Research in Higher Education*, 36, 23-39.
- U.S. Department of Defense. (2001). *Roadmap for national security: Imperative for change*. Phase III Report of the U.S. Commission on National Security/21st Century. Washington, DC: Government Printing Office.

Engineer of 2020 Project Methods

The Engineer of 2020 project involved a set of cross-sectional surveys of students, alumni, faculty, program chairs, and associate deans of undergraduate engineering in 120 programs at 31 randomly selected, nationally representative engineering schools, as well as students at 15 community colleges who indicated their intention to transfer to a four-year engineering program. Project staff designed the community college sample to maximize the number of responses from students in engineering-transfer programs. Because these programs are relatively small and few in number, a random sample would have yielded an insufficient number of cases to support the study's analyses and goals. With the help of a number of key informants in the community college and engineering education community, project staff identified twenty community college programs that met our criteria (large pre-engineering enrollments). Fifteen agreed to participate. In each institution, all students meeting the study's population specifications were invited to participate. All participating institutions are listed on the back cover.

A team of education and engineering researchers collaborated on the development of the survey-based instruments for engineering students, faculty, and administrators during a rigorous, two-year process. Instrument development included a year of interviews with engineering students, faculty members, and administrators at two universities (Penn State and City College of New York) and at two community colleges (Hostos Community College and Borough of Manhattan Community College, both in the City University of New York System) and in a two-year transfer program at Penn State—Altoona. All community college and four-year instruments were pilot tested and revised. Four-year student survey responses were weighted for each group separately to adjust for any response bias attributable to gender, race/ethnicity, class year, and engineering discipline. Community college students' responses were also adjusted to be representative of each institution's target population with respect to gender and race/ethnicity. Adjustments were also made within each group for variations in response rates across institutions in their group.

Overlooked Engineers summarizes the survey findings, distilling the responses of 1,245 community college students planning to transfer into four-year engineering programs. The report augments those responses with evidence from 846 four-year institution students who had transferred from a community college and from 4,085 "traditional" who began college in a four-year institution. More detailed information on these studies' development, cross-sectional sampling design, and data-collection and weighting procedures is available at <http://deepblue.lib.umich.edu/handle/2027.42/107460>.

Participating Community Colleges

Anne Arundel Community College (MD)
Austin Community College (TX)
Borough of Manhattan Community College(NY)
Brookdale Community College (NJ)
Community College of Baltimore County (MD)
Miami Dade College (FL)
Monroe Community College (NY)
Montgomery College (MD)

Prince George's Community College (MD)
Richland College (TX)
Santa Fe College (FL)
South Texas College (TX)
Union County College (NJ)
Valencia Community College (FL)
Wake Technical Community College (NC)

Participating Four-year Institutions

Arizona State University (Main & Polytechnic)
Brigham Young University
California Polytechnic State University²
California State University, Long Beach
Case Western Reserve University
Colorado School of Mines
Dartmouth College
Harvey Mudd College
Johns Hopkins University
Lafayette College
Manhattan College
Massachusetts Institute of Technology
Milwaukee School of Engineering
Mercer University
Morgan State University¹
New Jersey Institute of Technology
North Carolina A&T¹
Ohio Northern University

Penn State Erie, The Behrend College
Purdue University
Rose-Hulman Institute of Technology
Stony Brook University
University of Illinois at Urbana-Champaign
University of Michigan
University of New Mexico²
University of South Alabama
University of Texas, El Paso²
University of Toledo
Virginia Polytechnic Institute and State University
West Virginia University Institute of Technology

¹ Historically Black College or University

² Hispanic-Serving Institution

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