E2020 Study Methods

In 2004, the National Academy of Engineering published *Educating the Engineer of 2020: Visions of Engineering in the New Century* to encourage reform of undergraduate engineering education. That report inspired "The Engineer of 2020" project, two interrelated studies supported by the National Science Foundation. *Prototype to Production: Conditions and Processes for Educating the Engineer of 2020* (NSF-EEC-0550608) 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. *Prototyping the Engineer of 2020: A 360-degree Study of Effective Education* (NSF-DUE-061871) used in-depth case studies to identify curricular, instructional, organizational features that support undergraduate engineering education that is well-aligned with the goals of the *Engineer of 2020*.

The *Prototype to Production: Processes and Conditions for Preparing the Engineer of 2020* (P2P) study sought to contribute to the national dialogue surrounding the National Academy of Engineering's 2004 report, *The Engineer of 2020: Processes and Conditions for Preparing the Engineer of 2020*. The ultimate goal of the study was to assess the current capacity of undergraduate engineering programs to prepare engineers for the future. The project surveyed nationally representative samples of enrolled engineering students, recent graduates, faculty, program chairs, and associate deans for undergraduate engineering at 26 randomly-selected institutions, plus five of the six institutions participating in *Prototyping the Engineer of 2020: A 360-degree Study of Effective Education* (P360), an NSF-funded companion to P2P. Analyses of data from these surveys are contributing to the development of maps of the national landscape of undergraduate engineering education in the U.S. and revealing current levels of alignment between engineering program goals and the attributes specified in *The Engineer of 2020.* Analyses are also exploring the educational experiences of women and historically underrepresented undergraduate engineering students.

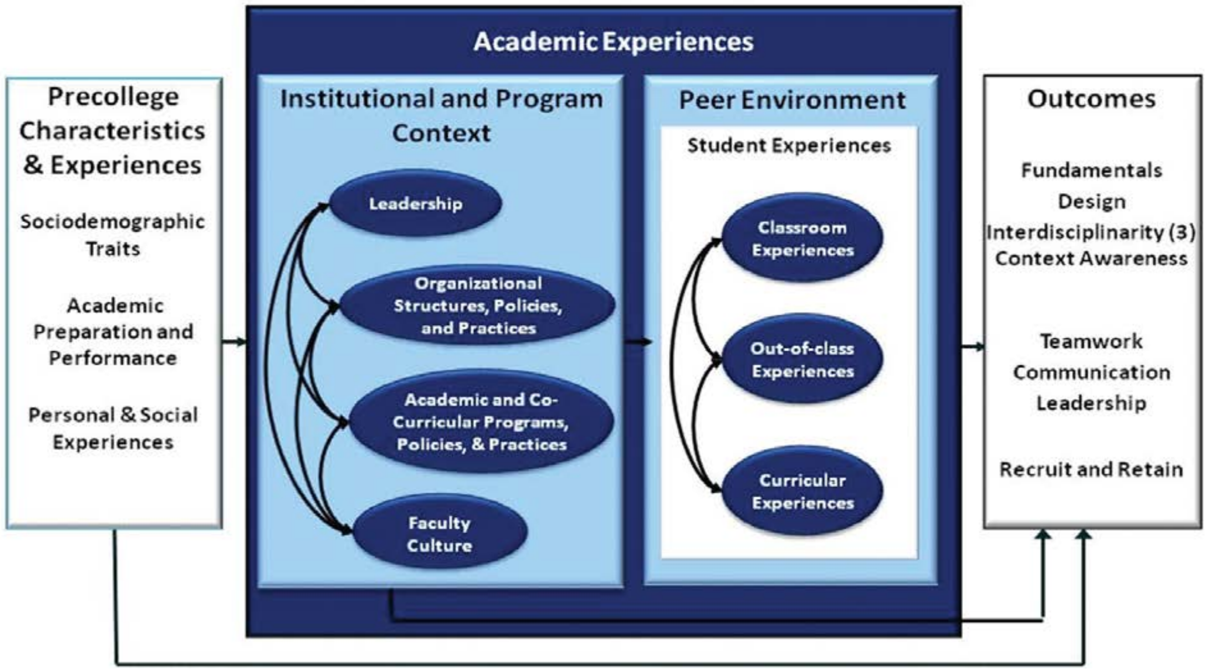
P2P also scanned an understudied sector of the engineering pipeline – two-year colleges that prepare students for transfer to bachelor's degree programs. Studying both two- and four-year student populations is enabling us to focus on students following different pathways to a four-year engineering degree and to explore if and how different aspects of engineering education may influence students' achievement and movement along their pathway depending on their gender and race/ethnicity. A key goal of the studies is to determine if variations in student experiences affect how students learn engineering and the decisions they make about whether to study engineering, whether to complete a degree, and whether, ultimately, to become an engineer.

Conceptual Framework

The Prototype to Production (P2P) and Prototyping the Engineer of 2020 (P360) studies rest on a conceptual framework originally developed by Terenzini and Reason (2005) that brings coherence to over 50 years of research in higher education (Figure A.1). In general, the model hypothesizes that pre-college characteristics shape students' engagement with various aspects of their institution. Students' levels of engagement are affected by a variety of curricular (e.g., general education coursework, academic major coursework, socialization to the major), classroom (e.g., pedagogies and instructor behaviors), and out-of-class experiences and conditions, all of which occur within an institutional context that includes an institution's internal organizational characteristics, structures, practices, policies, and faculty and peer cultures and environments (for a more detailed discussion, see Lattuca &

Litzinger, 2014). P2P survey questions, as well as P360 interview protocols, map onto this framework to organize data collection and analysis.

Figure A.1: Conceptual framework



P2P Study Methods

Survey Development and Site Selection

Developing the six survey instruments was a rigorous, two-year process for our team of higher education and engineering researchers. Procedures for preparing the questionnaires included: 1) literature reviews on key topics using the Association for the Study of Engineering Education database, Compendex, and various higher education databases; 2) individual interviews with administrators, faculty members, and alumni at Penn State University and City College of New York, the institutions of the study's co-principal investigators; 3) focus-group interviews with students at those same institutions. In preparing for each of these activities, team members developed a set of standardized protocols and underwent extensive training in qualitative research. We used what we learned from these information gathering efforts to develop the six survey instruments. To ensure content validity and that items/response options were comprehendible and appropriate, we pilot tested the instruments at Penn State prior to sending it to our target populations at our sampled institutions.

We used the American Society for Engineering Education's institutional database for guidance in drawing this study's samples using institution- and program-level information for the 2007–08 academic year for enrolled students and faculty. We used a 6 x 3 x 2 disproportionate, stratified, random sampling design with the following strata: 6 engineering disciplines (biomedical/bioengineering, chemical, civil, electrical, industrial, and mechanical); 3 levels of highest degree offered (bachelor's, master's, and doctoral); and two levels of institutional control (public and private). As such, institutions in the final sample were representative (with respect to type, mission, and highest degree offered) of the national population of institutions offering baccalaureate degrees in engineering.

We also "pre-seeded" this sample with the six case study institutions participating in the companion P360 qualitative study. One of the case study institutions offers only a general engineering degree, so we also included in the sample three institutions that offer general engineering degrees to serve as comparison institutions (giving us target populations in a total of seven disciplines). Together, these seven disciplines accounted for 70% of all baccalaureate engineering degrees awarded in 2007. Penn State's Survey Research Center randomly selected 23 additional institutions from the institutional population using the sampling framework, including two historically black colleges and universities and three Hispanic serving institutions. The final institutional sample is shown in Table 1.

Survey Administration and Response

Each of the six surveys was administered to the appropriate target-population group to gather data that would facilitate a better understanding of current curriculum and instructional techniques, learning environments, student educational experiences and outcomes, and institutional practices, policies, and cultures. Penn State's Survey Research Center was responsible for data collection through web-based questionnaires.

Table 1: P2P Institutional Sample

Research Institutions:	**Master's/Special Institutions**:
Arizona State University (Main & Polytechnic)[1]	California Polytechnic State University[3]
Brigham Young University	California State University, Long Beach
Case Western Reserve University	Manhattan College
Colorado School of Mines	Mercer University
Dartmouth College	Rose-Hulman Institute of Technology
Howard University	University of South Alabama
Johns Hopkins University	
Massachusetts Institute of Technology[1]	
Morgan State University[2]	**Baccalaureate Institutions**:
New Jersey Institute of Technology	Harvey Mudd College[1]
North Carolina A&T[2]	Lafayette College
Purdue University	Milwaukee School of Engineering
Stony Brook University	Ohio Northern University
University of Illinois at Urbana-Champaign	Penn State Erie, The Behrend College
University of Michigan[1]	West Virginia University Institute of Technology
University of New Mexico[3]	
University of Texas, El Paso[3]	
University of Toledo	
Virginia Polytechnic Institute and State University[1]	

[1] P360 Institution
[2] Historically Black College or University
[3] Hispanic-Serving Institution

With the exception of one campus, all data collection was completed by the end of 2009. On one campus, however, we encountered significant difficulties, including securing IRB review and approval in a timely fashion that would ensure an adequate participation rate from the target groups. Consequently, this institution's participation rates in virtually each survey population were so low the data received from the campus were not included in our analytical database, reducing the number of participating institutions to 31. We encountered similar difficulties in surveying “pre-engineering” students at some of the 15 community colleges campuses participating in the P2P study encountered similar (although the challenges were less-frequent and less-intensive). Table 2 provides information on the populations, respondents, and response rates for each survey.

Although the response rate for faculty members was on a par with those of earlier surveys completed by the research group, the student participation rate was significantly below expectations. Inquiries to, and reports from, colleagues, however, indicate the phenomenon was widespread nationally and not specific to the P2P surveys. Earlier evidence also indicated that response rates were declining nationally (Baruch, 1999; Porter & Umbach, 2006). College students in all fields are apparently suffering severe “survey fatigue.”

Table 2. P2P survey response rates for six stakeholder groups

	Number of Surveys Sent	Number of Respondents	Response Rate
Associate Deans	32	29	91%
Program Chairs	125	86	69%
Faculty	2,942	1,119	38%
4-year Students	32,737	5,249	16%
Alumni	7,307	1,403	19%
2- year Students	8,261	1,245	15%

Preparation and Cleaning of Data Sets (6)

Given the number of surveys and institutions, and because of the critical importance of working with accurate and valid data, project staff members invested considerable time and effort in “cleaning” each of the six survey datasets. The process entailed such activities as checking for “out-of-range” responses, examining the completeness of survey responses, and identifying response-sets (indicating a respondent is not seriously considering the questions). Dataset preparation (and subsequent analyses) required writing and debugging SPSS syntax defining the variables and response options for each item in each of the six datasets, as well as for item analyses, scale development, and scale reliability testing. Thus, six sets of programs were written, each for a very large, different, and complex dataset.

We accounted for differences in the proportional distributions between each group of respondents and their parent population. For four-year and two-year student surveys, cases were weighted to adjust for any response bias due to gender, race/ethnicity, class year, and discipline within an institution, as well as to adjust for differences in institutional response rates. The resulting weighted samples reflect the overall population of undergraduate engineers from our sample of institutions. Similar adjustments were made for the faculty dataset to correct for any response bias relating to academic rank, gender, race/ethnicity, discipline, and institutional response rate. See Table 3 for the characteristics of the P2P survey respondents. Table 4 provides information on the characteristics of the faculty population, sample, and survey respondents; Table 5 and 6 provide information on the characteristics of the engineering student and engineering alumni populations, samples, and survey respondents, respectively.

To maintain the maximum number of cases and, thus, statistical power, missing data were imputed for each sample group (except program chairs and associate deans) following procedures recommended by Dempster, Laird and Rubin (1977) and Graham (2009) using the Expectation-Maximization (EM) algorithm of the Statistical Package for the Social Sciences (SPSS) software (v.18).

Table 3. Characteristics of the population of 2008 engineering students, survey respondents, and their institutions

Characteristic	Students [a] (n = 5,082)	Alumni [b] (n = 1,380)	Faculty [c] (n = 1,389)
Discipline			
Biomedical	6.3%	6.3%	4.9%
Chemical	10.5	9.1	9.6
Civil	18.1	14.8	17.6
Electrical	18.9	32.1	34.4
General	6.6	5.3	5.3
Industrial	4.9	8.1	6.3
Mechanical	34.7	24.3	21.9
	100.0%	100.0%	100.0%
Gender			
Male	80.6%	79.3%	87.6%
Female	19.4	20.7	12.4
	100.0%	100.0%	100.0%
Race/Ethnicity			
African American	4.3%	4.6%	2.0%
Asian or Pacific Islander	13.2	13.4	17.2
Hispanic	11.2	6.3	2.9
American Indian/Alaskan Native	0.3	0.1	0.0
Other[d]	12.9	16.8	16.2
Foreign	7.3	5.6	10.6
Caucasian	50.9	53.2	51.1
	100.0%	100.0%	100.0%
Level			
Sophomore	22.3%		
Junior	35.0		
Senior	42.7		
Fixed-Term			12.4%
Assistant			20.1
Associate			26.0
Full			41.6
	100.0%		100.0%

[a] Weighted by discipline, class standing, gender, race/ethnicity, institutional response rate
[b] Weighted by discipline, gender, race/ethnicity, institutional response rate
[c] Weighted by discipline, gender, race/ethnicity, faculty rank, institutional response rate
[d] Other category includes Naturalized citizen, Middle Eastern, Multirace, and Other.

Table 4. Characteristics of the population of 2008 engineering faculty population, sample, and survey respondents

Characteristic	288-Institution Population [a] (N = 15,671)	31-Institution Sample [a] (n = 2,586)	Respondents [b] (n = 1,258)
Individual			
Discipline			
Biomedical	6.2%	6.5%	6.9%
Chemical	11.1	10.4	12.4
Civil	17.2	16.1	18.9
Electrical	33.1	36.5	46.9
Industrial	6.9	5.9	6.8
Mechanical	25.5	24.6	8.1
	100.0%	100.0%	100.0%
Gender			
Male	88.6%	87.9%	84.7%
Female	11.4	12.1	15.3
	100.0%	100.0%	100.0%
Race/Ethnicity			
African American	2.8%	4.3%	2.7%
Asian or Pacific Islander	23.5	24.7	10.8
Hispanic	3.4	3.0	2.6
American Indian/Alaskan Native	0.1	0.2	0.1
Other[c]	5.6	1.3	4,0
Foreign	0.1	0.1	14.2
Caucasian	64.6	66.5	65.6
	100.0%	100.0%	100.0%
Level			
Assistant	23.1%	21.8%	25.2%
Associate	26.1	25.4	25.4
Full	50.8	52.8	49.4
	100.0%	100.0%	100.0%

[a] Source: American Society of Engineering Education.

[b] Weighted by discipline and gender, and adjusted for institutional response rate.

[c] Other category includes Naturalized citizen, Middle Eastern, Multirace, and Other.

Table 5. Characteristics of the population of 2008 engineering student population, sample, and survey respondents

Characteristic	288-Institution Population [a] (N = 136,761)	31-Institution Sample [a] (n = 32,565)	Respondents [b] (n = 5,249 [c])
Discipline			
Biomedical	6.5%	6.5%	6.3%
Chemical	10.4	10.4	10.5
Civil	19.5	16	18.1
Electrical	21.8	21.4	18.9
Industrial	6.1	6	4.9
Mechanical	32.1	27.8	34.7
General	3.6	11.9	6.6
	100.0%	100.0%	100.0%
Gender			
Men	81.5%	80.7%	80.6%
Women	18.5	19.3	19.4
	100.0%	100.0%	100.0%
Race/Ethnicity			
African American	5.2%	5.9%	4.3%
Asian or Pacific Islander	12.1	12.3	13.2
Hispanic	6.5	6.1	11.2
American Indian/Alaskan Native	0.6	0.6	0.3
Other [d]	6.1	7.2	12.9*
Foreign	5.9	7.1	7.3
Caucasian	63.5	60.7	50.9
	100.0%	100.0%	100.0%
Level			
Sophomore	6.1%	27.9%	22.3%
Junior	39.0	29.0	35.0
Senior	54.9	43.1	42.7
	100.0%	100.0%	100.0%

[a] Source: American Society of Engineering Education.

[b] Weighted by discipline, gender, race/ethnicity, class year, and adjusted for institutional response rate.

[c] Weighted n may be smaller than unadjusted number of respondents due to missing data on a weighting variable.

[d] Other category includes Naturalized citizen, Middle Eastern, Multirace, and Other.

Table 6. Characteristics of the population of 2006 engineering alumni population, sample, and survey respondents

Characteristic	288-Institution Population [a] (N = 50,201)	31-Institution Sample [a] (n =8,294)	Respondents [b] (n = 1,380[c])
Individual			
Discipline			
Biomedical	5.7%	5.7%	6.3%
Chemical	8.5	12.5	9.1
Civil	17.1	16.9	14.8
Electrical	28.0	23.1	32.1
Industrial	7.2	7.5	8.1
Mechanical	31.2	31.8	24.3
General	2.3	2.6	5.3
	100.0%	100.0%	100.0%
Gender			
Male	79.9%	73.7%	79.3%
Female	20.1	26.3	20.7
	100.0%	100.0%	100.0%
Race/Ethnicity			
African American	4.7%	2.9%	4.6%
Asian or Pacific Islander	12.7	6.9	13.4
Hispanic	6.7	4.3	6.4
American Indian/Alaskan Native	0.5	0.1	0.1
Other[d]	7.1	8.6	17.1
Foreign	6.9	2.4	5.7
Caucasian	61.3	74.7	52.8
	100.0%	100.0%	100.0%

[a] Source: American Society of Engineering Education.

[b] Weighted by discipline, gender, race/ethnicity, class year, and adjusted for institutional response rate.

[c] Weighted n may be smaller than unadjusted number of respondents due to missing data on a weighting variable.

[d] Other category includes Naturalized citizen, Middle Eastern, Multirace, and Other.

To reduce data from several survey items into fewer, more reliable measures (scales), a principal axis factor analyses (Oblimin with Kaiser Normalization rotation) were completed. Each item was assigned to a factor based on the magnitude of the loading, the effect of keeping or discarding the item on the scale's internal consistency reliability (Cronbach's Alpha), and according to professional judgment. We formed factor scales by taking the sum of respondents' scores on the component items of a factor and dividing by the number of items in the scale, as recommended by Armor (1964).

Data Dissemination to Participating Campuses

As promised during our efforts to recruit institutions, project staff prepared campus-specific datasets for each survey. These datasets provide a strong foundation for engineering colleges and schools to undertake self-studies for internal program evaluations and assessments, resource allocation, ABET reaccreditation preparations, and future planning. Campus-specific datasets were then produced and written to CDs for shipping to each campus liaison.

The datasets sent to each campus were accompanied by a "User's Guide" specific to each of the five four-year institution surveys (enrolled students, alumni, and faculty; program chair and associate dean for undergraduate dean surveys were summarized in the aggregate because of the small number of respondents on each campus). Participating two-year campuses received similar materials for their "pre-engineering" students. The user's guides summarized the P2P project, the study's sampling design and methods for selecting institutional participants, data collection procedures, factor analyses and scale development practices, study limitations, the structure of the dataset for that survey (e.g., student, faculty), and examples of how to read and interpret the tables. The user's guides included a statistical summary report of each survey in the campus dataset. Summaries provided, for each item, number of respondents, the percentage distribution of responses, mean, standard deviation, statistical significance of differences between a campus's mean and those of each of three sets of comparison institutions (based on highest degree awarded), and effect sizes (an estimate of the magnitude of the difference between a campus's mean and that of each of the three comparison groups).

Data Base Management

The study's "master analytical file" contains multi-level information for each campus, including individual-level data (from students), program-level data (in the aggregate, from responding faculty members in each of the programs, as well as program-level information on structure, curriculum, and policy information from program chairs), engineering college-/school-level data (from ASEE databases), and institutional-level data (from the National Center for Education Statistics' Integrated Postsecondary Education Data Survey (IPEDS)). Development of the master file required matching (in a single file) data from individual students, from the combined faculty in the student's program, program-level information, college/school, and institution.

This master analytical file is the foundation for an extensive series of analyses both specific to the P2P study and in support of joint studies using data from the Prototyping the Engineer of 2020: A 360-degree Study of Effective Education (P360).

P360 Study Methods

The P360 study is a companion study to P2P. P360 consists of case studies of six engineering schools empirically identified as outperforming (in 2004) other engineering colleges in producing graduates with at least some of the attributes specified in the National Academy's *The Engineer of 2020*. P360 data were used in P2P instrument development and to identify relevant analyses of the P2P database. In turn, P2P data were incorporated into the case study reports sent to each of the six P360 institutions, and in study reports, conference proposals and presentations, and in journal articles.

The P360 case study institutions were identified through quantitative analyses of a nationally representative dataset developed for a previous study of the effects of ABET's outcomes-based EC2000 accreditation criteria and consultation with the E2020 National Advisory Board.

In 2007–08, the research team divided into three smaller teams of faculty members and graduate research assistants from engineering and/or education to conduct the six case studies. Data collection relied on multiple sources of evidence: 1) personal and group (or focus) interviews with faculty members, administrators, students, and professional staff (e.g., admissions and student support services); 2) observations of classes and notable academic programs; 3) archival records (e.g., meeting minutes) and other artifacts (e.g., websites, ABET self-study documents). Triangulating data from these sources enabled corroboration of facts and events at each case study site. We visited each case study institution at least twice to identify and study the factors that appeared to be shaping each institution's performance. Table 7 provides information about the participants by case study site.

Table 7. Table A.3: P2P survey response rates for six stakeholder groups

	Number of Surveys Sent	Number of Respondents	Response Rate
Associate Deans	32	29	91%
Program Chairs	125	86	69%
Faculty	2,942	1,119	38%
4-year Students	32,737	5,249	16%
Alumni	7,307	1,403	19%
2- year Students	8,261	1,245	15%

Each interview (individual and group) was transcribed verbatim, and the research team catalogued these and all other materials collected during site visits. After the second site visits, all transcripts, observations, notes, and documents (course syllabi, program descriptions, brochures, etc.) were combined into a dataset contained and analyzed in NVivo 8.0. During fall 2009 and spring 2010, research teams completed their analyses of the individual cases in preparation for a cross-case analysis, held in July 2010 with the full P360 research team who identified common themes across the six case study sites. Data from the P2P surveys of students and faculty members augmented and provided support for the validity of the qualitative analyses.

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