A Taxonomy of Engineering Matriculation Practices

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Introduction

There is clear evidence that engineering persistence varies significantly among institutions.[1] Institutional culture,[2] policy,[3] and selectivity[4,5] likely all play a role, but much research is needed to understand exactly which aspects of an institution most strongly influence student success. Even though retention in engineering is as good or better than other groups of majors in higher education,[1] retention in engineering continues to be one of the dominant topics of interest among engineering education scholars. This is not surprising given that the national average retention rate is 56% and can be as low as 30%. Also, while engineering retains students as well as other majors, engineering strives for a culture of continuous improvement, and some have speculated that there is potential to improve the retention rate to 80%.[6] Particularly in that attrition is more prevalent in the early semesters,[7] it is suggested that the matriculation model of an institution might account for a significant amount of the institutional variability in persistence.

Indeed, recent research shows a link between an institution's approach to engineering matriculation and important outcomes. Students entering in first-year engineering programs make different choices and experience different results than students who admit directly to a discipline.[8] There is also evidence of a relationship between an institution's approach to engineering matriculation and persistence, switching from other disciplines into engineering, transfer from other institutions to the institution's engineering program, likelihood of graduating in the first degree program selected, and time to degree.[9] Research combining the results of two surveys of first-year engineering programs describes a variety of characteristics of that particular matriculation model, yet that work also stops short of exploring first-year engineering programs in the context of other matriculation models.[10]

Clifford Adelman's metaphor of "paths" is used as a framework,[11] because it captures the fact that there are many ways for students to navigate the process of getting an engineering degree. Note that this is somewhat in contrast to "pipeline" metaphor, which suggests only one entry point with many "leaks" or exit points.[12,13] In keeping with this paths metaphor, this work considers a diversity of approaches by which students proceed from matriculating to an institution to being enrolled in a degree-granting engineering program and taking classes from faculty in that discipline.

To the extent that important outcomes are affected by the matriculation practices of an institution, it is important to the engineering education enterprise as a whole to know how prevalent the various matriculation models are. Independent of this systemic objective, institutions with a diversity of matriculation models have an interest in improving these various outcomes and, in some cases, have an interest in changing from one matriculation model to another. In support of benchmarking, continuous improvement, and to avoid reinventing the wheel, institutions have much to learn from knowing which institutions use a similar matriculation model, what matriculation models are being used by peer institutions, and what matriculation models are being used by aspirational institutions.

In this paper, both to establish a complete taxonomy and to classify all U.S. engineering programs using the that taxonomy, we research all 390 U.S. undergraduate institutions with ABET EAC-accredited engineering programs to determine the universe of practices leading to direct contact with a specific engineering major. Data were gathered from university, college, and departmental websites as well as clarifying telephone calls to admissions and engineering personnel. To further explain how this taxonomy may work in practice, in-depth, semi-structured interviews were conducted with College of Engineering representatives at 11 institutions to determine: 1) who makes the admissions decision for engineering students; 2) at what point may students declare an engineering major; and 3) the formal mechanism by which students are advised.

Research question

The overarching research question for this study is: "At what point is a first-time-in-college (not transfer) student at U.S. institutions formally admitted to a degree-granting engineering program and is any engineering course required in the first term of enrollment at the institution?" This question will be answered by collecting data from all 390 U.S. institutions that grant degrees accredited by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET), forming a taxonomy that classifies institutions according to the matriculation characteristics, and then classifying all U.S. institutions using that taxonomy. The results of this work will be distributed to the community of engineering institutions to be verified.

Methods

Efforts to classify institutional approaches to matriculation based on limited sets[9] are bound to result in a classification system that is incomplete. To develop and apply a more thorough taxonomy, three undergraduates were hired in Summer 2012 to locate and catalog institutional matriculation approaches for all 390 U.S. undergraduate institutions with ABET EAC-accredited engineering programs. Their work was verified and extended by one of the authors.

Data from the ABET website

An initial spreadsheet was developed by downloading information from the ABET website in May 2012.[14] The information downloaded from ABET was conditioned to have one row per U.S. institution with at least one EAC-accredited engineering program. As a resource for other data collection, the complete list of EAC-accredited programs and degree names was concatenated into a single column. This initial spreadsheet had the following fields for 390 institutions:

1. School Name (as shown in ABET records)
2. Location (City, State, Country)
3. Website (URL for institutional website)
4. Programs and Degree Names (list of all EAC-accredited programs and degree names separated by semicolons)

This initial spreadsheet also contained Accreditation Dates, Accredited Campus Locations, Criteria, and Date of Next Comprehensive Review. The accreditation dates and the criteria used for accreditation were also concatenated. These fields were not needed for the present study, so they were removed from the spreadsheet used for data collection.

Data from the American Society for Engineering Education

The American Society for Engineering Education (ASEE) gathers profile data from participating institutions each year.[15] The data are as accurate and as complete as that which each institution voluntarily submits in a given year. Each profile has sections for Institutional Information, Undergraduate Engineering Information, and Graduate Engineering Information.[16]

Some data from the ASEE profiles were considered in describing the matriculation model of an institution. From the Institutional Information, contact information can provide a channel for clarification by a local official, the academic calendar is crucial to understanding the structure of the first year, and admissions information can help understand how students start their academic careers through the admissions process. Quite a bit more information from the ASEE profiles is useful in a contextual sense—enrollments, campus setting, governance, faculty number and description, student expenses and financial aid, demographics of engineering students, and selectivity information.

Some data from the ASEE Profiles can be accessed using a data mining tool.[17] Quantitative measures of Degrees, Enrollments, Faculty Ethnicities, Other Degree Fields, Other Enrollment Fields, Other Faculty Gender Fields, Faculty, Institution and College of Engineering, Research Expenditures, and Student Appointments are available. The data available in the data mining tool is not useful for taxonomic purposes, but it has the potential to be useful in providing contextual information once a taxonomy has been created and applied—for example, to note whether certain undergraduate matriculation models are common at institutions that have larger graduate enrollments or if certain approaches are more common at institutions that do not enroll graduate students. The data mining feature as well as the larger Profiles dataset is likely to be of use to others who use this taxonomy as a research tool.

From the ASEE Profiles page, four additional fields were gathered:

5. ASEE Profile name / link (the name of the institution name in the ASEE profiles, and the name was linked to the ASEE profile page for that institution)
6. undergraduate engineering available (only institutions with “Yes” were kept)
7. graduate engineering available
8. engineering technology available

From each ASEE profile, our research team routinely gathered another three fields:

9. Institution type (Public/Private)
10. Institution setting (Urban, Suburban, Small Town, Rural)
11. Academic calendar (Semester, Quarter, Trimester)

Note that for institutions that did not participate in the ASEE Profiles in 2011, these data had to be determined along with all other data collected from website review and from institutional contact. In 2011, 311 of the 390 institutions with EAC-accredited programs participated in the ASEE profiles. By considering other years of the ASEE Profiles, this basic information (which does not change frequently) was secured for 348 of the 390 institutions.

Data gathered directly from institutional websites or other institutional sources

A wide variety of other information was of direct interest to the formation of a taxonomy of matriculation approaches. While the detailed procedures of data collection are more complicated, they are not of interest here. Of greater interest are the aims of the data collection. Data were collected from institutional websites and occasionally from institutional personnel where clarification was required to answer the following questions:

- What is the first engineering course taken; how many credits is it; in what term is it taken; is it disciplinary, multi-disciplinary, or general in its approach?
- If there is a second introductory engineering course before core disciplinary courses are taken, what are the answers to those questions for the second engineering course taken? (Repeat for third and fourth engineering course as needed.)
- Are the above courses required or optional? Are they required or optional for some or all majors or for undecided students?
- Who advises engineering students when they are first admitted, and is this different for fully qualified students, students admitted as at-risk, undecided students, and students of other majors interested in switching to engineering?
- Does the institution support alternative pathways through a temporary major for transitional students or transfer agreements?
- How does engineering fit into the governance structure?
- Who makes admissions decisions for engineering applicants?
- What milestones must a student have passed to designate a degree-granting engineering major (matriculation, science/math courses, non-technical courses, some number of enrolled terms or credits)? Is there an accelerated pathway for high-performing students?
- Are there additional requirements to be admitted to certain engineering disciplines (a cap on the number of students, a GPA cutoff, or other criteria such as a test)?

Data quality and reproducibility

Data were collected by three undergraduates working fairly independently, so it was necessary to plan ahead to gather sources of information as well as the information itself. In particular, during the data collection process, multiple web addresses were recorded, adding six new fields:

12. Undergraduate course catalog website
13. Primary engineering website
14. Prospective student website
15. Admissions website
16. Advising website
17. Transfer student website

Where information was located obscurely, undergraduates recorded the source in spreadsheet notes. Although the three undergraduates contributed many hours over the summer to this project, they were not able to complete the project due to its scope and complexity. One of the authors gathered the data collected by the undergraduates, completed data collection, located missing data where possible, and verified the most critical information to the extent possible. Only institutional representatives can be sure to describe their matriculation approach thoroughly and accurately, so the community must have input to the final stages of this work.

Interviews of college of engineering personnel

We conducted semi-structured interviews with college of engineering representatives at 11 institutions during the 2010-11 academic year. Among the eleven institutions, Florida A&M University (FAMU) and Florida State University (FSU) share one college of engineering and thus, we often refer to 10 colleges of engineering among the 11 institutions. We interviewed representatives about their admissions policies and practices, their first year curriculum, and the nature of advising for first year students. These interviews help identify some of the significant features of the process of entering engineering in U.S. engineering colleges. The ten colleges of engineering were chosen as a convenience sample from among the partners of the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD).[18,19] MIDFIELD contains student academic records at eleven public institutions that are located primarily in the southeastern U.S.. Partner institutions have larger engineering programs on average compared to over 300 colleges with engineering programs, resulting in a population that includes more than 10% of engineering graduates of U.S. engineering programs.

Findings

There are a variety of findings from this work—the taxonomy is generated as an empirical finding of the data collection process, a clearer picture of matriculation processes results from the interviews of engineering college personnel, and the evaluation of each institution’s approach to matriculation according to that taxonomy is of interest both individually and in the aggregate.

A Taxonomy of Engineering Matriculation Practices

A taxonomy of approaches to matriculation in engineering has been created based on our findings from surveying the matriculation approaches of U.S. institutions with EAC-accredited programs. The decision tree in Figure 1 places 368 (94%) institutions in one of the shaded taxonomic classifications. We expect that the remaining 22 (6%) institutions would be identified with one of the existing classifications, but the institutional website did not provide enough information to select one.

The highest level of the taxonomy considers two factors:

1. whether a student is expected to, permitted to, or restricted from enrolling in a specific engineering degree program at matriculation,
2. whether an introductory engineering course is required in the first term by all, some, or none of the engineering programs in an institution.

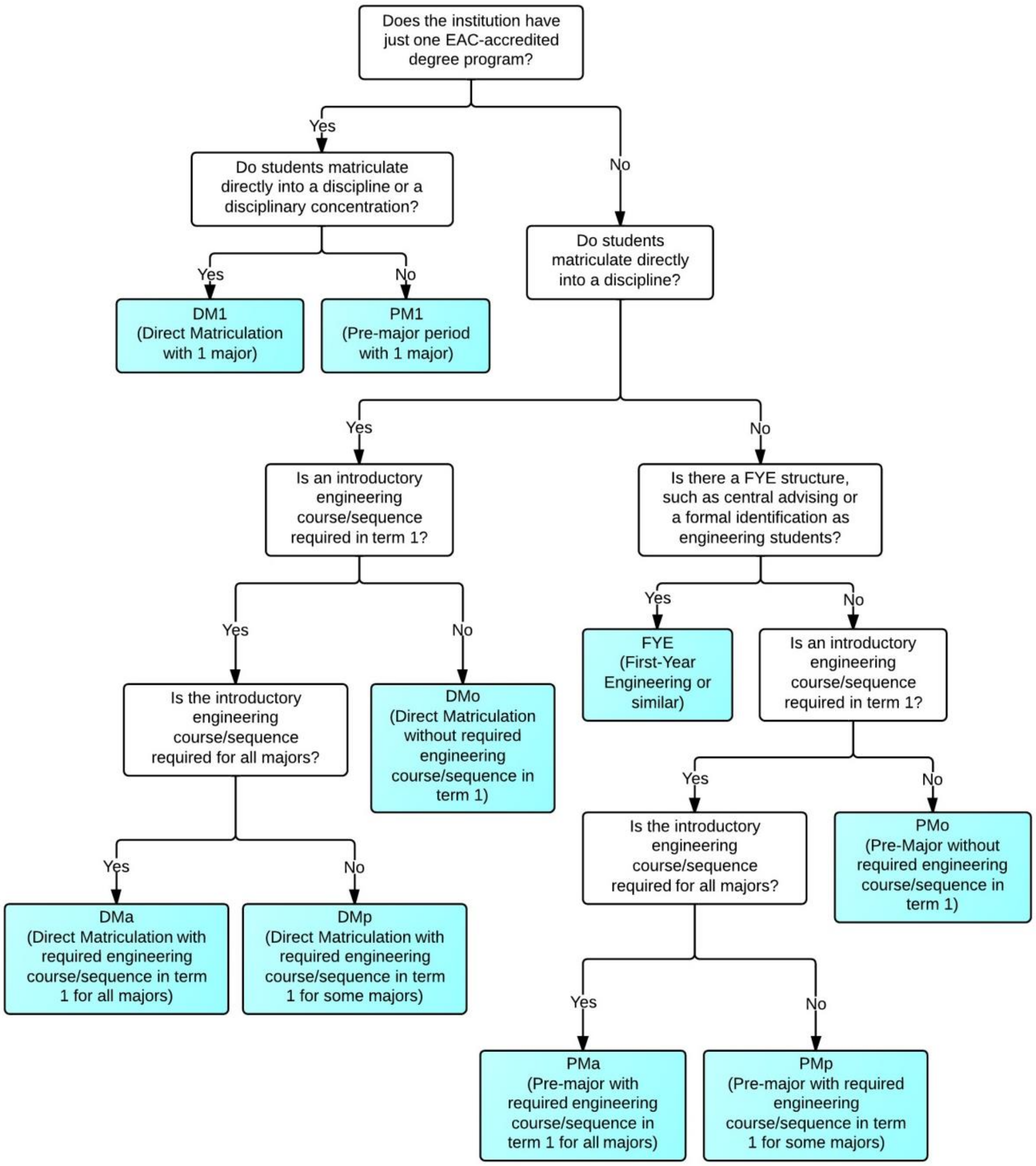

Figure 1. The decision tree for classifying institutions

Note that "intro engineering" course here does not necessarily have to be a course with "Introduction to…" in its title nor does it have to be the same course for all majors. We aim to determine if engineering students or students who are interested in engineering can get early exposure to the discipline via course(s) offered in college of engineering. Therefore, we count any engineering course available in the first term as an introductory engineering course. These introductory courses include such diverse courses as "Introduction to Visualization and CAD," "Introduction to Mechanical Engineering," "Engineering Projects and Design," and simply "Introduction to Engineering" and may include an overview of available engineering disciplines, introduction to a specific discipline, computer skills for engineers, and hands-on projects. Some classifications are dominated by a set of programs with a more restrictive definition that can help identify programs. Such patterns as well as other special clarifications are noted in Table 1 along with the number of institutions falling into each classification.

Table 1. Classifications, number of institution in each classification, and notes for engineering matriculation taxonomy

Label	Description	No. (Freq.)	Notes
DM1	One engineering major available; students matriculate into the major directly at matriculation.	35 (9%)	In some institutions, the "Engineering" major includes specializations, but all choices are made at matriculation.
PM1	One engineering major available; students do not matriculate directly in that major or can select it generally, but cannot move into one of its concentrations at matriculation.	26 (7%)	In some institutions, the "Engineering" major includes specializations, but students cannot choose a specialization until 1-4 semesters after entry.
DMa	More than one engineering major; students matriculate directly to a specific engineering discipline; introductory engineering course/sequence is required in the first term by all majors.	153 (39%)	
PMa	More than one engineering major; students are required to take one or more engineering courses in the first term by all majors, and they must meet certain requirements to be formally admitted to an engineering major after 1-4 terms.	26 (7%)	Most take general engineering courses until they are admitted to the degree program. Some take disciplinary engineering courses before admission to major.
DMp	More than one engineering major; students matriculate directly to a specific engineering discipline; introductory engineering course/sequence is required in the first term by some but not all majors.	50 (13%)	Most commonly the course/sequence is required for students who enter as undesignated engineering.
PMp	More than one engineering major; students are required to take one or more engineering courses in the first term by some majors, and they must meet certain requirements to be formally admitted to an engineering major after 1-4 terms.	19 (5%)	
DMo	More than one engineering major; students matriculate directly to a specific engineering discipline; introductory engineering course/sequence is optional or unavailable in the first term for all majors. Introductory engineering course may be required but later than term 1.	5 (1%)	

Label	Description	No. (Freq.)	Notes
PMo	More than one engineering major; engineering courses is either optional or unavailable in the first term for all majors; students must meet certain requirements to be formally admitted to an engineering major after 1-4 terms.	8 (2%)	Mostly engineering programs do not require students to take engineering course before admission to major.
FYE	Students are identified as engineering students but are not permitted to specialize for some period of time. Institutions in this category must have some other first-year engineering structure (a required course/sequence, central advising, etc.) to distinguish them from PMa/PMp/PMo.	46 (12%)	Some programs are classified in this category even though they do not call themselves “First-Year Engineering” or similar.
TBD	To be determined: not enough information to determine which category it belongs to	22 (6%)	

Observations regarding groups of institutions in each classification

Extensive analysis of the classification of the various U.S. institutions is premature before fact-checking with the institutions. Nevertheless, some preliminary observations are useful in validating the taxonomic classification and to learn about the U.S. engineering education system.

- DM1 and PM1: On average, institutions with one EAC-accredited major have lower engineering enrollment as compared to population averages (22 TBD institutions are excluded from the population for computation purpose). These institutions are much less likely to be urban and much more likely to be rural than population averages. PM1 is nearly twice as likely to be found at a private institution as population averages.
- DMa and PMa: These institutions have slightly lower engineering enrollment than population averages. Unlike PM1 institutions, PMa institutions are significantly more likely to be urban and public institutions than population averages.
- DMp and PMp: These institutions have higher engineering enrollment, are more likely to be urban institutions, and are much more likely to be public institutions than population averages.
- DMo and PMo: Only a few institutions use these models. Engineering enrollment, degree of urbanization, and institution type (public versus private) are similar to population averages.
- FYE: Institutions with FYE programs have significantly higher engineering enrollment than population averages.

Classification of MIDFIELD institutions

Classifying the MIDFIELD institutions according to this taxonomy achieves two purposes. First, we can be conscious of how the development of the taxonomy may have been affected by the schools where the interviews were conducted. Second, we can gain interesting perspective on the representativeness of the MIDFIELD institutions based on how they are classified. For the 2012-2013 school year, the MIDFIELD schools fit into the taxonomy we have developed as follows:

- DMa University of Colorado, North Carolina A&T, UNC-Charlotte
- DMp University of Florida, Georgia Tech
- FYE Clemson, FAMU-FSU, NC State, Purdue, and Virginia Tech

It is interesting to note that both the FAMU-FSU College of Engineering (which is one college of engineering shared by two universities) and NC State previously would have been categorized as DMa institutions (until 2004 and 2012 respectively) but determined that an FYE model would provide institutional advantages, be more likely to allow students to make an informed choice about disciplinary fit, would provide students with an early milestone to gauge their progress towards earning an engineering degree, and would increase student retention in engineering.

Interview findings

Admissions processes. The colleges of engineering have varying degrees of influence on the admissions process for their students. Although the institutions make the offer of admissions for all engineering undergraduate students, students who meet standards set forth by the colleges of engineering for high school GPA and test scores at three of the ten schools will automatically be admitted to the college, although those standards are not necessarily made public. One of these three will offer admission to Arts and Sciences undecided for less qualified students with a migration option to engineering. A fourth school admits a portion of the first-year class through a guaranteed admissions policy for highly qualified state residents; others are admitted competitively with somewhat less qualified students offered admission to Arts and Sciences undecided with an engineering migration option. In three colleges of engineering, anyone admitted to the university is eligible to be admitted to the college as they consider the university admissions standards high enough to qualify any admitted student for the study of engineering. Three colleges of engineering set criteria for admission and/or a request to yield a certain number of first year students in collaboration with university admissions, but the university ultimately decides who is admitted and may choose to ignore the criteria. All three will also admit slightly less qualified students to the university to Arts and Sciences undecided from which they may migrate to engineering.

Interviews with students have been conducted as part of the larger MIDFIELD matriculation project at several of these schools and results from the interviews will be reported separately. Preliminary analysis suggests that few students choose their institution because of its matriculation model; indeed, many students do not know until after they have been accepted or even enrolled what type of matriculation model their institution has. Most report that they chose these schools because they are considered to be the best engineering school in the state where they reside, which, among other things, includes the cost advantage of in-state tuition. Therefore, it would appear that the colleges of engineering have chosen their matriculation models for reasons unrelated to student recruitment.

Progression Requirements. At schools with a First-Year Engineering program, students must complete a set of courses including Calculus 1 and 2, Physics 1, Chemistry 1, English 1, and the Introduction to Engineering sequence satisfactorily to be admitted to an engineering degree program. Students at non-FYE institutions must also satisfactorily complete the same courses, but matriculation into an engineering degree program is not affected. Some departments at five institutions have enrollment restrictions that may include a higher GPA, a formal application / examination, an enrollment cap, and/or admission to an internship program; one of those institutions applies enrollment restrictions in the admissions process.

Advising. In most of the FYE programs, all students are advised by staff advisors or first-year engineering faculty assigned to the first-year engineering department. At one FYE institution, advising is handled by faculty or staff in the preferred major for those who enter with a preference; otherwise, advising is done in the engineering Dean's office. At one of the DMa institutions, students must satisfactorily complete the core courses to matriculate to department advising; first year students are advised through the office of engineering student affairs until they have done so. Students at the remaining institutions are advised in their departments once they matriculate or by the engineering deans office otherwise with the exception of one institution where undecided engineering students are advised by university advising.

It is noted that the MIDFIELD partner institutions represent only three of the nine categories identified in the taxonomy, which indicates a limitation of MIDFIELD in understanding the impact of the choice of matriculation model. However, 64% of the schools nationally fit into one of these three categories and they educate 81% of engineering students in the U.S., so MIDFIELD contains data that is representative of the matriculation experience of a vast majority of students and programs.

Conclusions

The taxonomy of matriculation practices developed in this work provides researchers and practitioners with a common language for discussion of engineering matriculation practices. As this taxonomy has been applied to U.S. institutions with EAC-accredited programs, the findings have use for institutional benchmarking and improvement. This information should be used cautiously prior to fact-checking by the institutions. The database used for analysis will be made available for public comment – and it is hoped that the information gathered through this study can be added to the ASEE profiles so that the information can be kept current.

The patterns noted above are interesting and provide surprising opportunity for discussion given the small number of contextual variables included at this preliminary stage (before fact-checking). This work will complement efforts by others to understand and classify the approaches to introductory engineering courses.[20,21] Together, these two approaches will do much to help describe the engineering education system. Beyond preliminary observations listed in this work, future work will explore extensively how institutional characteristics align with different matriculation models.

This work has various limitations that should be noted. Since MIDFIELD only contains student data of eleven institutions, this work is not yet able to determine the correlations between various matriculation modes and student outcomes such as retention rates. Furthermore, while this work focuses on institutional matriculation practices, it is likely that institutional culture, policy, and selectivity are interrelated – that policies and structures that are effective at highly selective institutions may not have the same effect at institutions with more liberal admissions policies. Similarly, some policies that would be effective at any institution may be inconsistent with the culture of certain institutions. It is also important to note that the nature of advising is sometimes difficult to determine from institutional websites so institutions are placed into categories, particularly FYE, with the acknowledgement that our information may be incorrect or incomplete until reviewed by institution officials.

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References

1. Ohland, M.W., S.D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R.A. Layton, "Persistence, Engagement, and Migration in Engineering," *J. Eng. Ed.* **97**(3), July 2008.
2. Godfrey, E. (2007). Cultures within cultures: Welcoming or unwelcoming for women? *Proceedings of the 2007 ASEE Annual Conference.* Honolulu, HI.
3. Brawner, Catherine E., Sharron A. Frillman, and Matthew W. Ohland, "A Comparison of Nine Universities' Academic Policies from 1988 to 2005." (ERIC: ED508293), February 2010, 42 pages.
4. The Center for Institutional Data Analysis and Exchange (C-IDEA). 2000. 1999–2000 SMET Retention Report. Norman, OK: University of Oklahoma.
5. Morrison, C., Retention of minority students in engineering: Institutional variability and success. NACME Research Letter, 5, 3-23, 1995. National Action Council for Minorities in Engineering: New York.
6. Fortenberry, N.L., J.F. Sullivan, P.N. Jordan, D.W. Knight, *Engineering education research aids intruction.* Science, 2007. **317**: p. 1175-1176.
7. Min, YoungKyoung, G. Zhang, R.A. Long, T.J. Anderson, and M.W. Ohland, "Nonparametric Survival Analysis of Undergraduate Engineering Student Dropout," *Journal of Engineering Education*, **100**(2), April 2011.
8. Brawner, C., M. Camacho, R. Long, S. Lord, M. Ohland, and M. Wasburn, Work in Progress: The effect of engineering matriculation status on major selection," *Proc. Frontiers in Education 2009*, San Antonio, TX, October 18-21, 2009.
9. Orr, M.K., M.W. Ohland, R.A. Long, S.M. Lord, C.E. Brawner, and R.A. Layton, "Engineering Matriculation Paths: Outcomes of Direct Matriculation, First-Year Engineering, and Post-General Education Models," *Proc. 2012 IEEE/ASEE Frontiers in Education Conference*, Seattle, WA, October 3-6, 2012.
10. Brannan, K.P. and P.C. Wankat, "Survey of First-Year Programs," Proceedings of the 2005 American Society for Engineering Education annual Conference and Exposition, June 12-15, 2005 in Salt Lake City, UT.
11. C. Adelman, "Women and men of the engineering path: A model for analyses of undergraduate careers," Washington, DC: Department of Education, 1998.
12. Berryman SE. (1983). *Who Will Do Science?* New York: Rockefeller Foundation.

13. T. L. Hilton and V. E. Lee, "Student interest and persistence in science: changes in the educational pipeline in the last decade," *Journal of Higher Education*, vol. 59, pp. 510-26, 1988.
14. http://main.abet.org/aps/Accreditedprogramsearch.aspx
15. http://profiles.asee.org/profiles?year=2011&commit=Go
16. http://www.asee.org/papers-and-publications/publications/college-profiles/about-the-data/engineering-profiles-description
17. http://www.asee.org/papers-and-publications/publications/college-profiles#Datamining_Tool
18. Ohland, M.W., G. Zhang, B. Thorndyke, and T.J. Anderson, "The creation of the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD)" *Proc. Amer. Soc. Eng. Ed.*, Salt Lake City, Utah, June 2004.
19. https://engineering.purdue.edu/MIDFIELD
20. http://www.nsf.gov/awardsearch/showAward?AWD_ID=1042030&HistoricalAwards=false
21. Reid, Kenneth, and Tamara Knott (2012). Developing a Classification Scheme for "Introduction to Engineering" Courses. Catalyzing Collaborative Conversation session T4E. *IEEE/ASEE Frontiers in Education 2012 Conference*, Seattle, WA, October 3-6, 2012.