# A Comparative Study of Engineering Matriculation Practices

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Matthew W. Ohland is Professor of Engineering Education at Purdue University and a Professorial Research Fellow at Central Queensland University. He has degrees from Swarthmore College, Rensselaer Polytechnic Institute, and the University of Florida. His research on the longitudinal study of engineering students, team assignment, peer evaluation, and active and collaborative teaching methods has been supported by over $12.8 million from the National Science Foundation and the Sloan Foundation and his team received Best Paper awards from the Journal of Engineering Education in 2008 and 2011 and from the IEEE Transactions on Education in 2011. Dr. Ohland is past Chair of ASEE's Educational Research and Methods division and a member the Board of Governors of the IEEE Education Society. He was the 2002–2006 President of Tau Beta Pi.

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Catherine E. Brawner is President of Research Triangle Educational Consultants. She received her Ph.D.in Educational Research and Policy Analysis from NC State University in 1996. She also has an MBA from Indiana University (Bloomington) and a bachelor's degree from Duke University. She specializes in evaluation and research in engineering education, computer science education, teacher education, and technology education. Dr. Brawner is a founding member and former treasurer of Research Triangle Park Evaluators, an American Evaluation Association affiliate organization and is a member of the American Educational Research Association and American Evaluation Association, in addition to ASEE. Dr. Brawner is also an Extension Services Consultant for the National Center for Women in Information Technology (NCWIT) and, in that role, advises computer science departments on diversifying their undergraduate student population. Dr. Brawner previously served as principal evaluator of the NSF-sponsored SUCCEED Coalition. She remains an active researcher with MIDFIELD, studying gender issues, transfers, and matriculation models in engineering.

**Ms. Xingyu Chen, Purdue University, West Lafayette**

Xingyu Chen is a Ph. D. student in the School of Engineering Education at Purdue University. She obtained her master's degree in operational research and bachelor's degree in mathematics from Zhejiang University, China. She started to pursue her Ph.D. degree in engineering education at Purdue in 2010. She is working with Dr. Ohland on the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), and also on the Integrated Postsecondary Education Data System (IPEDS) database.

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## Project goals

The original major goals of this project are to: 1) describe the matriculation patterns and disciplinary choices of engineering students using MIDFIELD and 2) explore the underlying reasons for patterns found with MIDFIELD through interviews with sophomore engineering students at selected MIDFIELD partners. A third goal has since been added to develop a taxonomy of engineering matriculation practices that encompasses all undergraduate engineering degree programs in the United States.

## Major activities

- Developed and refined Taxonomy of Engineering Matriculation Practices that applies to all 390 ABET accredited undergraduate engineering programs in the US. The taxonomy has been presented to engineering educators for feedback at ASEE. After clarifying the model used at some institutions where it could not be determined from the institution's website, the data gathered will be transmitted to ASEE. Brian Yoder of ASEE has agreed to make the information public (probably through the ASEE Profiles project) so that institutions can validate the information and keep it updated.
- Taxonomy is groundwork for a dissertation that relates matriculation model, first year engineering curriculum, and institutional characteristics (e.g., Carnegie classification, selectivity).
- Conducted 30 interviews with sophomore engineering students at three institutions yielding a total of 61 interviews at six institutions over two years.
- Verified transcripts of recorded interviews.
- Conducted preliminary analysis of interview data.
- Presented 4 conference papers; One additional paper is under review for ASEE conference.
- Preliminary taxonomy groups have been used to analyze patterns in retention and major selection.
- We held the second project Advisory Board meeting on August 6, 2013 with Rebecca Brent (chair) of Education Designs, Inc., Mary Steiner from the University of Colorado, and Patrice Noel from the University of Wyoming. The Board reviewed ahead of time various work products and questions from the research and provided helpful feedback and direction.

## Specific objectives

The MIDFIELD database will be used to map the matriculation, third-semester major, and graduation of first time in college students at each of the partner institutions. We will look at aggregate trends and differences among and between institutions and generate frequency and descriptive statistics related to the enrollment and persistence trends of undergraduate engineering students from the MIDFIELD institutions. The MIDFIELD database will be used to

define the following distributions based on institution, gender, ethnicity, SAT/ACT scores and high school GPA where available, and socioeconomic status if feasible: (1) Students matriculating in engineering; (2) Students enrolled in an engineering discipline at the third semester; and (3) Students who graduate in an engineering discipline.

Descriptive statistics of carefully defined populations from the MIDFIELD database will be used to describe the pathways above. Related to the first goal are subgoals to answer the following questions:

- When students in FYE programs declare their first engineering major, do they do so in the same proportion as students directly admitted into those engineering disciplines?
- When engineering undesignated students declare their first engineering major, do they do so in the same proportion as students directly admitted into those engineering disciplines?
- At the third semester, is the distribution of major choice of students who matriculated directly into a discipline different from that of students who matriculated into FYE programs or who were engineering undesignated?
- Is there a difference in the percentage of students who switch majors and the number of times they switch based on mode of entry?
- What is the first-year academic performance of students who remain in FYE or in engineering undesignated status in their 3rd semester compared with those who have declared a major by that time?
- What is the 6-year graduation outcome (graduated as engineers, graduated as non-engineers, still in school, left the database) of students who remain in FYE or in engineering undesignated status in their 3rd semester compared with those who have declared a major by that time?
- Is there a difference in pre-college qualifications (high school GPA, SAT scores, high school SES) of students entering FYE programs or with a declared major or who are engineering undesignated? Would these qualifications explain differences in major selection and 6 year graduation?
- Is there a differential effect of FYE programs on women and/or people of color?

**Parallel with goal 3 of identifying a taxonomy for engineering matriculation models, goal 2** identifies the matriculation model and the advising process at each of the partner institutions and interviews engineering students to explore the effect of these on disciplinary choice and persistence. Specifically we will seek to answer the following questions:

- What is the impact of the matriculation model on student major selection?
- What is the impact of the home (university, college, discipline) of first-year advising on student major selection?
- What is the impact of the personnel (faculty, staff) engaged in first-year advising on student major selection?
- What is the impact of the enrollment restrictions (GPA requirements, quotas) on student major selection?

## Major accomplishments

The taxonomy itself described in Major Activities is itself our most significant accomplishment during this project period. All practitioners and researchers with whom we have discussed this want the data made public as soon as possible. For our own research purposes, MIDFIELD institutions have now been reclassified according to the new taxonomy.

Retention in engineering is almost 4 percentage points higher at institutions where students are required to take a Common Introduction to Engineering (CITE) (55.9%) than in institutions where they are not (52.1%). About the same proportion of students (21.0% to 21.8%) leave engineering, but are retained at the institution, so students who take a CITE are less likely to leave their institution by the 8$^{th}$ semester.

The highest retention in engineering was for designated students with a required CITE at 56.7%, followed by undesignated students with a required CITE at 55.7%, designated without a required CITE at 52.8% and finally undesignated without a CITE (48.7%). Undesignated students without a CITE were also most likely to leave the institution rather than change to a non-engineering major (28.5%) followed by designated students without a CITE (26.6%), designated students with a CITE (25.8%) and undesignated with a CITE (21.2%). The CITE is associated with higher retention in engineering and the institution and may help students find their place.

Even without a required CITE, students who take a semester or more to decide are more likely to remain in their first major choice (41.9% vs. 37.9%, a 4% difference), but a required CITE helps even more (48.8% vs. 39.5%, an 8.7% difference). This difference is conservative—more of the designated students will remain in their first choice of engineering major even if they realize it is not the best fit to avoid the transactional cost of changing majors. Patterns may also be influenced by institutional or program characteristics such as the relative ease with which students can change majors. Still, it is interesting to note that even students who selected a discipline at matriculation were slightly more likely to remain in their choice if they were required to take a CITE course.

CITEs affect disciplinary distribution, yet institutional variations in size, quality, and selectivity of various programs require us to interpret the findings with caution. Undesignated students are more likely to choose ME, tempered by the presence of a CITE. Undesignated students are less likely to choose EE, and this outcome seems to be unaffected by the introductory course. Civil enrollment is increased by a required course for both groups, and with or without a course, students who wait to decide are more likely to choose it than those who designate at matriculation. Industrial engineering results are largely driven by one institution with a large program. CpE, ChemE, and Aero are similar in that a required introductory course decreases enrollments from the designated group but increases enrollment of undesignated students.

Interviews with sophomore students were conducted at six institutions and have answered four research questions so far: 1) why did students choose their institution? 2) Did the matriculation model of the institution affect the students' decision to choose that institution? 3) Why did students choose their engineering majors? And 4) Did an introduction to engineering course, if taken, affect the students' choice of major?

Students chose MIDFIELD institutions because of a combination of their engineering reputation, proximity, and in-state tuition. The vast majority of students interviewed did not know at the time they were applying what the matriculation model of their school was. For most of those who were aware of the model, the matriculation model did not affect their decision to choose that school – cost was a much more important consideration.

Engineering disciplines attract students for different reasons. Civil engineers like infrastructure, including roads and water systems. Students who switched to civil engineering from environmental engineering indicated that they did so in many cases because of the lower chemistry requirements. The reasons students most often cite for choosing chemical engineering is an aptitude for chemistry and math and often a dislike for physics. Chemical engineering students also mentioned earning potential more than other majors and an initial desire to attend medical school. Many of the students who chose electrical and/or computer engineering were exposed to it through robotics competitions in high school. Six of the nine students in these majors reported having a family member who is an engineer, the highest percentage of any of the majors. Industrial was the major chosen most often by students who entered undecided or from another discipline. Two switched to industrial engineering from biology, one from a smaller engineering discipline, and one from undecided engineering. Mechanical engineering students cite the breadth of the field as a key reason for choosing it. More students in this discipline indicated that they enjoy working with their hands than students in other fields. These students also tend to prefer physics to chemistry.

Many students decided on their engineering major in high school or even earlier. Others, believing that their aptitude for math and science made engineering a good choice for them, were less sure of their specific major when they entered the university. FYE programs are designed to force students to wait to declare a major until they have been exposed to their options in engineering. Other students entered their institutions with an undecided engineering major, voluntarily taking extra time to decide. Students at several MIDFIELD institutions are free to declare a major when they enter the institution, and the majority do so. However, of the students interviewed, only a third (12/36) were in the same major at the time of the interview during their sophomore year as they declared when they entered the institution. Some of these students changed majors the summer before their first year or immediately on arrival after further research between the time they were accepted and the time they enrolled. More often, however, there was something about the first year experience, particularly introductory courses, that had an effect on the students' sophomore major.

At the three schools where a CITE sequence is required, many of the students found the portion of the introductory course where the different disciplines were introduced to be either confirmatory of the major they were sure they wanted or it helped them find a discipline that better suited their interests and skills than what they thought the wanted. Of the non-CITE schools, two do not require any introduction to engineering course but offer them for students who wish to take them. Of those two, half of the students interviewed at one of them chose to take either an introduction to a discipline course or an engineering survey course, the latter being highly recommended for undecided students. The undecided students who took the engineering survey course found it very helpful for choosing a major. The third non-CITE school requires

students to take an introduction to engineering course but they may choose from introduction to the various disciplines, an engineering projects course, and an engineering survey course.

## Dissemination

As indicated earlier, sharing the detailed taxonomy with ASEE will result in broad dissemination and impact. We have shared our work primarily through conferences to gain the help of the engineering education community in framing the taxonomy and our other results. We have presented our work in four presentations at 3 conferences, and have another under review for presentation at this ASEE conference. We have engaged the community with several workshops and presentations as well.

- Orr, M., Ohland, M., Long, R., Brawner, C., Lord, S., and Layton, R. (2012). *Engineering Matriculation Paths: Outcomes of First-Year Engineering, Direct Matriculation, and Post-General Education Models.*. Frontiers in Education Annual Conference. Seattle, WA..
- Chen, X., Brawner, C., Ohland, M., and Orr, M. (2013). *A Taxonomy of Engineering Matriculation Practices.* American Society for Engineering Education Annual Conference. Atlanta, GA..
- Orr, M., Brawner, C., Ohland, M., and Layton, R. (2013). *The Effect of Required Introduction to Engineering Courses on Retention and Major Selection.* American Society for Engineering Education Annual Conference. Atlanta, GA.
- Brawner, C., Ohland, M., Chen, X., and Orr, M. (2013). *The Effect of Matriculation Practices and First-Year Engineering Courses on Engineering Major Selection.* Frontiers in Education Annual Conference. Oklahoma City, OK.
- Ohland, Matthew W. in Symposium "Connecting Education and Research on Retention in Engineering," Organizers Suzanne G. Brainard, Elizabeth Litzler (2012). *How institution policy, curricular structure and program culture affect students.* American Association for the Advancement of Science. Vancouver, BC.
- Ohland, M.W. (2012). *Keynote Address*. First-Year Engineering Experience Conference. Pittsburgh, PA.
- Meyers, K.L., H. Matusovich, M.W. Ohland (2012). *First-Year Engineering Programs*. First-Year Engineering Experience Conference. Pittsburgh, PA.
- Ohland, M.W. (2012). *How Institutional Policy, Curricular Structure and Program Culture Affect Engineering (and Other) Students*. Seminar for Learning and Teaching Education Research Centre, Central Queensland University. Rockhampton, QLD, Australia.
- Meyers, K.L., H. Matusovich, M.W. Ohland (2013). *Addressing Key Issues Relating to the Execution of First-Year Engineering Programs*. American Society of Engineering Education Annual Conference, First-Year Programs Division Workshop. Atlanta, GA..
- Meyers, K.L., H. Matusovich, M.W. Ohland (2013). *Addressing Key Issues Relating to the Execution of First-Year Engineering Programs*. First-Year Engineering Experience Conference. Pittsburgh, PA.
- Brawner, C. E., Orr, M. K., and Ohland, M. W. (2014). *The Accidental Engineer.* American Society for Engineering Education (under review). Indianapolis, IN.

## Impact on engineering education

Providing the taxonomy developed by the research teach has the potential for impact on both research and practice. Xingyu Chen's related dissertation research will expand knowledge of the field.

The project team intends to collaborate with Ken Reid at Ohio Northern University on a proposal to study the impact of specific introductory course elements on retention in engineering and in major. Dr. Reid and his team have developed a classification scheme for the components of an introductory course. Through studying the syllabi of the introductory courses in MIDFIELD and the outcomes of students who are exposed to the various course components, we hope to be able to advise the engineering education community on the effectiveness of various introductory course modules.