New Orleans JAZZED about Engineering Education

Paper ID #17431

The Evolution of the Freshman Engineering Experience to Increase Active Learning, Retention, and Diversity—Work in Progress

Dr. Tracy Jane Puccinelli, University of Wisconsin - Madison

In 2011, Puccinelli joined the Biomedical Engineering (BME) Department as a Lecturer and Outreach Coordinator. As part of the BME design faculty, she works on curriculum development, as well as innovative approaches for teaching design. Puccinelli coordinates BME outreach, advising BME seniors as they develop interactive, hands-on activities for K-12 students that teach biomedical engineering concepts. Additionally, in 2012, she began teaching an introductory engineering course (Introduction to Engineering Design) to incoming freshmen in the College of Engineering. In 2014, Puccinelli became an Assistant Faculty Associate as well as a coordinator for the Introduction to Engineering Design course, which has become a popular course with more than 900 students enrolled per year, and an expected enrollment of 1000 students this coming academic year.

Dr. Mary E. Fitzpatrick, University of Wisconsin - Madison

Mary Fitzpatrick, Ph.D. is an educational psychology researcher and former engineer. She directs the student programs and initiatives offered by the Diversity Affairs Office at UW Madison College of Engineering, evaluates program outcomes for diversity initiatives and conducts original research in the area of underrepresented individuals and organizational climate in engineering education and the workplace. Dr. Fitzpatrick holds an undergraduate degree in Biomedical Engineering, a master's degree in Electrical Engineering and was a practicing engineer for GE, Microsoft and other leading companies before earning her Ph.D. in educational psychology.

Dr. Gene Paul Masters, University of Wisconsin - Madison

The Evolution of the Freshman Engineering Experience to Increase Active Learning, Retention, and Diversity--Work in Progress

Abstract

This work in progress will describe the process of developing two new freshman engineering courses at the University of Wisconsin-Madison College of Engineering to increase active learning, retention, and diversity. Our Introduction to Engineering and Design course is currently undergoing significant changes due to the desire to emphasize active and cooperative learning and increase diversity. Moreover, with our new direct admission model, there is a need to provide incoming engineering freshmen with a supportive and informative environment. At this time, our engineering college is also facing substantial budget cuts to education, requiring partial departmental buy-in to participate in multidisciplinary freshman engineering courses. Given the current situation, budget constraints, and available resources, we seek to determine the best course of action to provide a supportive and active learning environment and increase retention in underrepresented racial/ethnic minorities and women of all ethnicities (URMs). We have analyzed retention data, and will survey engineering students (from the past three years, including those who left engineering) on their freshman engineering experiences. This data will provide information to aid in the development of our two new freshman engineering courses.

Introduction

Our college of engineering at UW-Madison has twelve majors (nine departments) and has had approximately 1200-1300 new freshmen each year. We have offered several interdisciplinary freshman engineering courses over the past few decades, each slightly different. Currently, in our largest course (~1000 students per year out of 1200-1300 total engineering freshman), Introduction to Engineering and Design (Intro 160), students participate in lectures covering design topics that span multiple disciplines of engineering. In the laboratory section of this course, they work in teams of 8-12 to solve a real-world, client-based engineering design problem proposed mostly by individuals in the local community and industries. The other introduction to engineering courses (Intro 101 and 102) are much smaller (~100 students collectively), and do not have hands-on labs with client-based projects.

As a result of budget constraints, the college has recently decided to end all existing college-wide interdisciplinary introductory engineering courses (as of the end of the spring 2016 semester) and has tasked us with developing just one or two new engineering college interdisciplinary freshman courses to take their place. We are currently developing two new freshman engineering courses to be piloted Fall 2016: a one credit seminar course, Introduction to Engineering; and a two credit hands-on design course, Design Practicum. These two new courses will likely take the place of all other multi-disciplinary freshman engineering courses. This makes it critical that every effort is made to develop cutting-edge courses that satisfy all engineering departments.

With this fresh start to the freshman engineering experience, we have the opportunity to significantly change course style and content. In the United States, retention of underrepresented minorities including women continues to be significantly lower than non-underrepresented men. [1] Our engineering college continues to have a large gender and ethnicity gap, with just 19.9 % female, 3.5% Latino, 1.8 % African American, 0.8 % American Indian/ Alaskian Native, and 0.2 % Native Hawaiian/ Pacific Islander as of Fall 2014. Our engineering college is concerned about this lack of diversity and we are hoping to make significant improvements in retention of URMs including women.

History of Introduction to Engineering Courses

Our first introduction to engineering course was introduced in 1986 (Intro 101), and was essentially a survey course that covered various engineering disciplines. It was lecture only, without any team-based projects or hands-on labs. In 1995, Intro 160 was introduced and is described as a course that provides incoming freshman with an overview of engineering based on a "hands-on" experience with a client-centered engineering design project. Intro 160 covers the same topics as Intro 101 in a lecture format, but also includes this hands-on lab. Due to its popularity, the course has expanded to serve almost one thousand students per year. The class meets twice a week in lecture format where the design process is taught and significant societal issues are discussed, such as: clean water, sustainability, energy, health care, and engineering ethics. The class also meets once per week for three hours of lab where students work on teams to solve real-world engineering problems with real clients. This course has undergone continuous evolution to improve both the lecture and lab components. The lectures have evolved to include guest speakers that cover engineering grand challenges that showcase the interdisciplinary nature of engineering design and the current societal issues these students will face. The Intro 160 course has also adjusted to include more emphasis on interpersonal soft skills for effective project and team management, as well as more technical training such as engineering shop training, computer-aided design, electronic notebooks, and technical communication. In 2008, another course was developed (Intro 102), which is similar to Intro 101, but also includes lectures with engineering grand challenges. Again, this Intro 102 does not have any projects or hands-on labs. Intro 160 remains the most popular of all introductory freshman courses. As our college undergoes change, we hope to create new courses that: evolve with advancing technology, include current engineering grand challenges, offer engaging and interactive lectures, and encourage underrepresented minorities, including women, to stay in engineering.

Freshman Engineering Course Requirements

Our engineering college has not yet decided how many introduction to engineering credits will be required for freshman, however the new one credit seminar style course, Introduction to Engineering, will be required for all engineering freshmen. Up until now, two credits have been required for all engineering departments, and they had the freedom to choose from a variety of

interdisciplinary courses. A minimum of two credits will be required going forward. (The Equity and Diversity Committee, and the Diversity Affairs Office are trying to change this requirement to three credits.) The old interdisciplinary courses are no longer available, thus departments must either participate in both new interdisciplinary courses, or create another course of at least one additional credit. Departments that have chosen not to participate in the two credit course will have to provide at least one more credit of introduction to engineering to their freshmen. One department, mechanical engineering, has chosen to create their own new freshman course. This course is not interdisciplinary. The other departments not participating in Design Practicum already have department specific courses that satisfy the requirements. Again, these courses are not interdisciplinary.

Structure of the New Interdisciplinary Freshman Courses

The following descriptions are the current summaries of the two new freshman introductory interdisciplinary engineering courses. Some content has yet to be determined. In particular, curriculum to provide an inclusive classroom and active learning strategies are still in the development phase.

The one credit seminar course, Introduction to Engineering, will be required for all engineering freshman (approximately 1100 expected freshmen Fall 2016) and will cover topics of interest to incoming engineering freshmen during the first few weeks such as: engineering societies/student organizations, study abroad, campus resources, and career services. The next few weeks will have panels of faculty representing 3-4 engineering majors per week. These faculty have been asked to briefly (10 minute presentations) present the most exciting and current research and events within their department. The subsequent lectures will be seminar style with guest speakers (both faculty and industry have been invited) from a variety of engineering disciplines focusing on the grand challenges of various engineering disciplines. Students will be assigned weekly reading assignments related to the lecture topics of the week, and will be quizzed on both the lectures and the reading assignments.

The two credit course, Design Practicum, is a hands-on design course with lectures and labs that will introduce students to relevant topics in engineering including: problem solving, team design, innovation, information technology, engineering, ethics in engineering, community engagement and social responsibility. This course will require partial departmental financial support, thus not all departments are currently committed to participating due to budget concerns. Just over half of our engineering college is currently planning to participate, with approximately 600 students expected to enroll this coming year. (Fall 2016/Spring 2016) This course is modeled after the popular Intro 160 course and will have teams of students solving real-world engineering problems with real clients. In addition, this course will offer more department involvement via online videos and lectures. Collectively, the online videos, lectures, and tutorials will provide a "flipped classroom" style course. Students will complete assignments that align with learning

the engineering design process including: online assignments, solve engineering problems, build and manage teams, fabricate and test prototypes, give presentations, and write a technical report.

Active Learning Strategies

Active learning is generally defined as anything in addition to the passive listening of a traditional lecture format. There is some disagreement regarding the most effective active learning strategies [2, 3], thus we plan to evaluate various strategies in our new courses and make necessary improvements each semester.

As of now, three main areas of active learning are planned for the new courses. First, an in-class response tool (Top Hat) will be used in the new Introduction to Engineering seminar course and potentially in the Design Practicum course. This tool allows students to interact with speakers by answering questions throughout lectures on any smart device. Top Hat will be piloted this semester for one set of lectures (two sections) in our current Intro 160 course. Top Hat was chosen by our IT department after extensive research on several platforms. Our university is currently negotiating a campus-wide contract, thus many courses plan to implement Top Hat. Second, we plan to develop online quizzes to test students on weekly lectures, reading assignments, and online material in both new courses. Online quizzes are also being piloted this semester in our Intro 160 course. There is evidence to suggest that quizzes promote self-reflection and a deeper understanding. [4] These online quizzes can also serve as assessment of the course content, allowing course coordinators to make adjustments in real-time based on quiz results. [3, 5] Third, particularly in the hands-on course, we will provide online tutorials, videos, and lectures--commonly known as "flipping the classroom." [5] This strategy will be largely implemented in the Design Practicum course to allow more time in class for hands-on learning and applying learned material including team-based problem solving, fabrication, and testing. Examples of online material will include the design process, departmental videos of current engineering research on our campus, and computer-aided drawing tutorials.

Numerous active learning strategies exist, thus these courses will likely implement a variety of new strategies each semester to determine the most effective methods. Other methods shown to increase learning and engagement include: relating lecture content to current events; case studies; and team assignments. [6] Recently, we were made aware of a campus-wide program that provides education interns to work on educational projects, such as ours. We submitted a project proposal and hope to partner with this campus education resource to learn strategies that have already been successfully implemented in courses at our university. We also look forward to hearing new active learning ideas at the ASEE conference this summer. Course evaluations, student surveys, and instructor feedback will all contribute to the constant evolution of our teaching strategies.

Inclusive Classroom Strategies

Providing an inclusive classroom is a relatively new initiative at our engineering college as we strive to reach the goal of increasing diversity. We plan to implement several known strategies in our new courses, and continue to research this topic through the summer. Most studies suggest that small groups provide more opportunity for inclusiveness, particularly in underrepresented groups including women. [7] While this can be implemented in the smaller sections of the Design Practicum course, the larger lectures in the Introduction to Engineering course will be a challenge. One option is to allow small break-out sessions to answer questions posed by the guest speaker during lectures. Another inclusive strategy is to provide a diverse set of teaching styles to engage a more diverse population. Our active learning strategies may play a duel role in that they may more effectively engage students, and also provide a more inclusive environment by offering multiple methods to learn the same material. [8]

We are also working closely with our College of Engineering Equity and Diversity Committee (EDC) to develop bias training for all instructors (tentatively piloted summer 2016), and new curriculum (tentatively piloted Fall 2017) on bias and diversity. Unfortunately, much of this work has yet to be completed and may not be available when these new courses begin this fall 2016.

Retention Data Analysis

We compiled and analyzed retention data (to department) in the college of engineering to determine if the introduction of freshman engineering courses appeared to have any impact on retention rates in the college of engineering, particularly with underrepresented minorities including women. It must be stated that this analysis is merely correlation and many factors exist that cannot be accounted for with the limited data.

As shown in Figure 1, our overall retention rate (to department) of all engineering students has increased from 57% in 1985 to 68% in 2012. In 1986, the first introductory freshman engineering course began (Intro 101), however retention rates remained relatively unchanged until Intro 160 began in 1995. There is an obvious upward trend after Intro 160 began. After the college began requiring one introductory to engineering course for all freshman in 2005, there was a brief increase in retention from 66% to 68%. The next four years showed a decline in retention rates down to 63%, with retention rates showing a gradual upward trend again starting in 2010. Intro 102 began in 2008, in the middle of the downward trend. The last data point shows overall average retention rates back up to 68% in 2012.

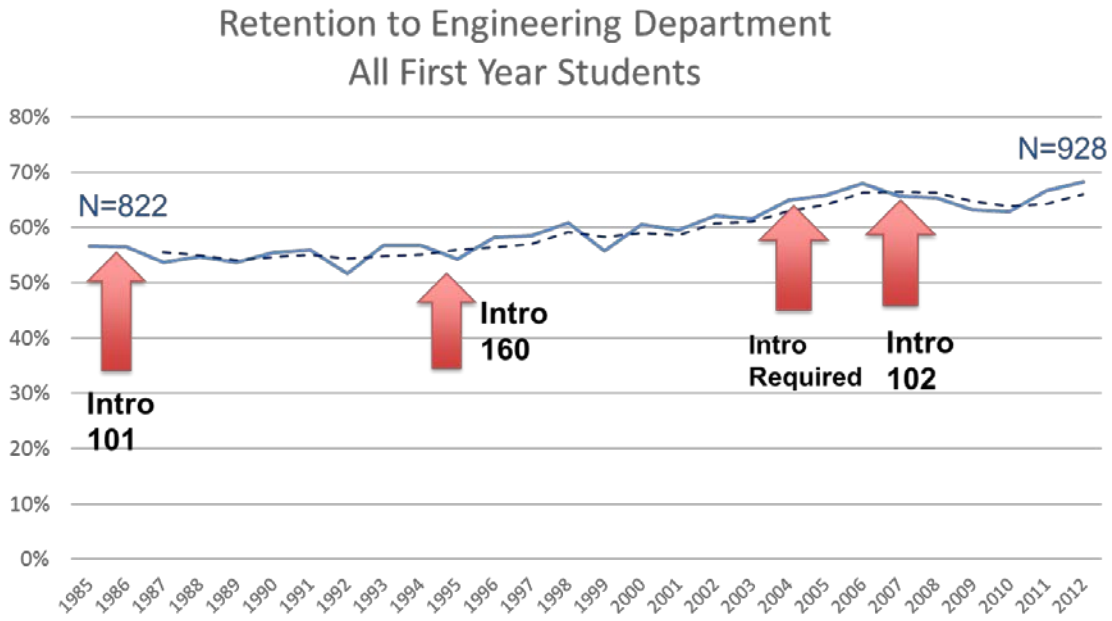

Figure 1. Overall Retention to Engineering Department. This graph illustrates the overall average retention rate (percent retained) of all engineering freshman since 1985. N represents the total number of engineering students (N of 822 in 1985 and N of 928 in 2012). The large arrows indicate when new freshman introductory engineering courses began, and when an introductory engineering course became a requirement. The dotted line represents a three year rolling average.

This overall retention to department data was then categorized by gender (Figure 2a) and by targeted minority vs. non-targeted students (Figure 2b) to determine if retention rates among underrepresented students including women had improved with the addition of introductory courses. Figure 2a does show a slightly better average increase of retention of women, with a 14% increase vs. a 11% increase in men since 1985. The data showing retention of targeted minorities (Figure 2b) shows that overall retention rates have increased 26% from 35% in 1985 to 61% in 2012. This is significantly higher than non-targeted/non-minority students, where there was an overall average increase in retention rate of 11% from 58% in 1985 to 69% in 2012. There appears to be a slight decline in retention rates among targeted minorities from 1985 until 1995. After Intro 160 began in 1995 there was a gradual increase in retention through 2012 with both women and targeted minority students. This trend is not apparent with the non-targeted group of students. However, the numbers of minority students are low and retention rates have a high variance.

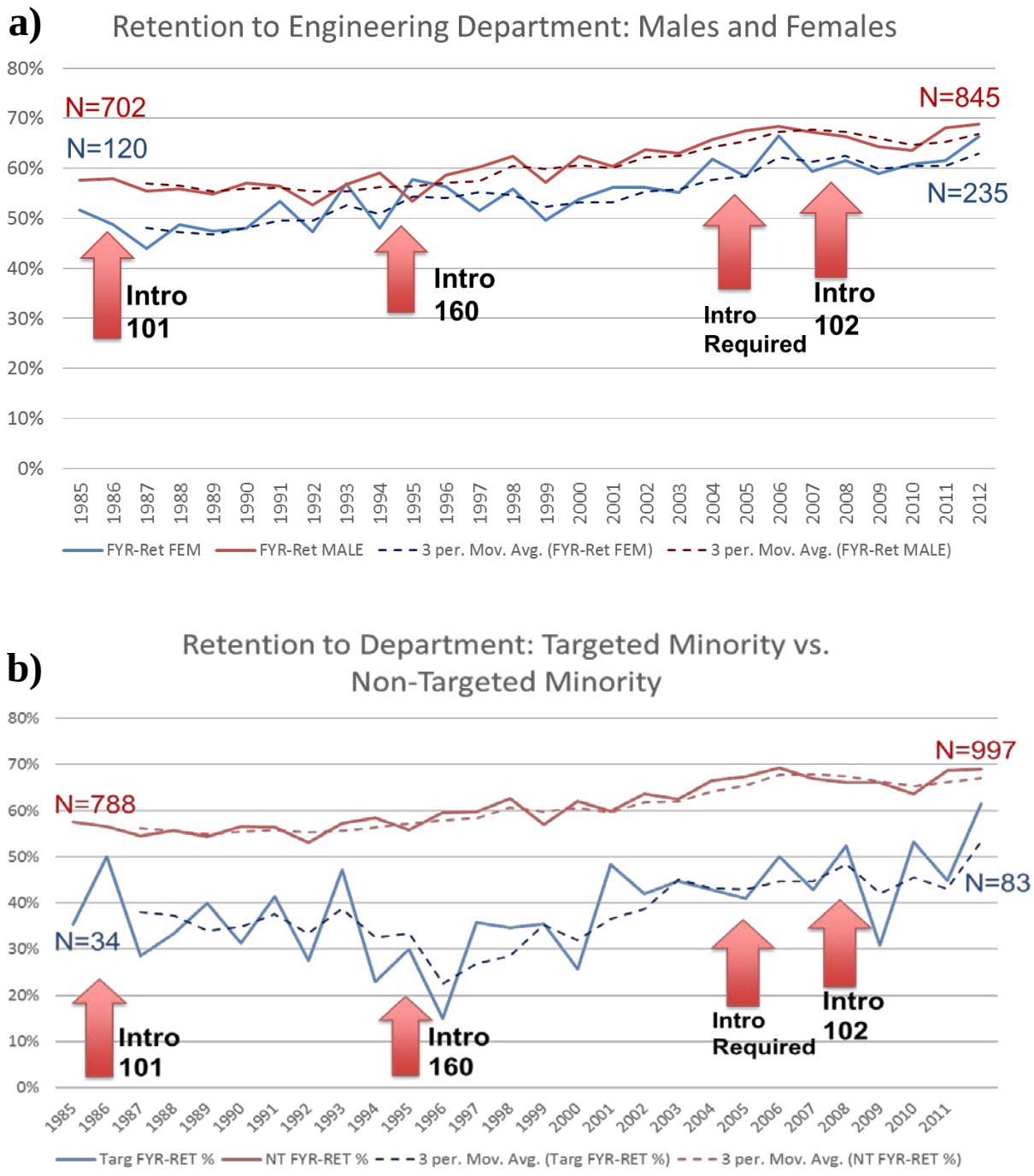

Figure 2. Overall Retention to Engineering Department by gender. N represents the total number of engineering students per group. The large arrows indicate when new freshman introductory engineering courses began, and when an introductory engineering course became a requirement. The dotted lines represent a three year rolling average. **a)** This graph illustrates the overall average retention rate (percent retained) of all male (red line) vs. female (blue line) engineering freshman since 1985. **b)** This graph illustrates the overall average retention rate (percent retained) of all targeted minority (blue line) vs. non-targeted (red line) engineering freshman since 1985.

We then analyzed retention data by introductory freshman engineering course. We compared Intro 101, Intro 102, and Intro 160 to those not enrolled in an introductory course. There was not a significant difference in retention rates among all engineering students, or with underrepresented minorities including women by introductory course. (Data not shown.) Again, to reiterate, this analysis is merely correlation and there are numerous confounding factors we cannot account for that could affect retention rates.

Student Survey

We recently developed a student survey to gain a better understanding of the influence of introduction to engineering courses on students' academic decisions. We intend to use this data to further develop the two new introduction to engineering freshman courses to be piloted Fall 2016. This survey was just distributed to all students who took an introduction to engineering course during the past three years. The survey branches and asks different questions to those students who have since left our engineering college. Most questions use likert scale answers ranging from strongly disagree to strongly agree, with a few questions offering comment boxes for students to type answers. Comment boxes are also available when students answer positively and/or negatively to some questions to obtain more information. The survey includes the following questions:

- Screening questions: Did you take an introduction to engineering course? Are you continuing to pursue a degree in the College of Engineering? I changed or plan to change my major to: (comment box). Have you been accepted into an engineering department? (prompts to select department)
- What introduction to engineering course did you take? (offers list and text box)
- My introduction to engineering course...(not all are listed here)
    - increased my interest in a career in engineering
    - made me more likely to complete an undergraduate degree in engineering
    - influenced my educational decisions about engineering
    - taught me valuable technical concepts and skills
    - increased my sense of confidence in my ability to succeed in engineering
    - provided me with good connections to engineering faculty members
    - taught me about how to contribute to and work well on a diverse engineering team
    - taught me how basic math and science (calculus, chemistry, physics) concepts are applied in engineering projects
    - helped me feel welcome in the College of Engineering
    - helped me obtain internships and co-ops
- Please provide any additional comments you have about your Introduction to Engineering course: (comment box)
- Branch from screening: I changed my major from Engineering to another major because…
    - I became more interested in another major

    - I did not meet minimum academic requirements of my engineering major or the College of Engineering
    - I did not like the faculty in the College of Engineering
    - I did not like the teaching methods in the College of Engineering
    - I did not like the other students in the College of Engineering
    - I did not feel like I belonged in engineering
    - I did not think I would like working in an engineering field or as an engineer
- Please describe any other reasons for changing my major from engineering, or provide comments on any of the questions about changing your major: (comment box)
- Demographic information (includes: year in school, cumulative GPA, US Citizenship Status, first generation college, financial aid, gender, race/ethnicity)

This survey was just sent to approximately 4000 students (those who have taken and completed an introduction to engineering course within the past three years) and 729 have responded thus far. Survey reminders will be sent until the end of the semester to those not responding and results will be analyzed later this summer.

Conclusion

The data shown herein appears to support (by correlation) the widely held belief that introductory freshman engineering courses are associated with an increase in retention rates.[9-11] Other research has shown that hands-on projects with context may contribute to deeper learning, particularly with women. [12] However our initial analysis of course-specific retention data does not clearly support this. (Data not shown.) Thus, the course structure of hands-on, team-based engineering design alone may not be enough to increase retention of underrepresented minorities including women. Freshman engineering students that are considered underrepresented may feel excluded when placed on teams of primarily white and male students. We have already established a successful engineering design course with a hands-on project with a real client (Intro 160) and plan to continue to offer hands-on engineering design in our new two credit course, Design Practicum. However, exact strategies beyond this to improve retention and inclusiveness are yet to be determined. What constitutes an inclusive environment in the classroom? The aforementioned survey to students who took an introductory engineering course from the past three years will hopefully partially answer this question.

In the next few months, we will finalize details of the curriculum and structure of the two new freshman engineering courses: Introduction to Engineering (1 credit lecture), and Design Practicum (2 credit lecture and hands-on lab). We will meet with faculty from every engineering department to ensure all areas of engineering are represented, both in the seminar series, and also in the hands-on design course curriculum. We also recently offered an internship project for a few graduate students to aid us in the development and implementation of active learning tools, and to analyze the new survey data later this summer.

Many questions still remain as we develop these new courses: How can we more effectively engage freshman engineering students in both lecture and lab? What are the best active learning strategies? How do we provide a more inclusive environment in our classrooms? How do we teach students to be more culturally aware, inclusive, and supportive of a diverse team? What course structure will contribute to increasing retention of URMs including women in engineering? These are questions we hope to answer with continued analysis of retention data and survey results, as well as interacting with our College of Engineering Equity and Diversity Committee and the ASEE community.

References

[1] C. Corbett and C. Hill, "Solving the equation: the variables for women's success in engineering and computing," 2015.

[2] M. Prince, "Does active learning work? A review of the research," *Journal of Engineering Education,* vol. 93, pp. 223-231, 2004.

[3] J. W. Gikandi, D. Morrow, and N. E. Davis, "Online formative assessment in higher education: A review of the literature," *Computers & Education,* vol. 57, pp. 2333-2351, 2011.

[4] M. Stansfield, E. McLellan, and T. Connolly, "Enhancing student performance in online learning and traditional face-to-face class delivery," *Journal of Information Technology Education,* vol. 3, pp. 173-188, 2004.

[5] C. J. Brame, "Flipping the classroom," *Retrieved, August,* vol. 29, p. 2013, 2013.

[6] A. Srinath, "Active Learning Strategies: An Illustrative Approach to Bring out Better Learning Outcomes from Science, Technology, Engineering and Mathematics (STEM) Students," *International Journal of Emerging Technologies in Learning,* vol. 10, 2015.

[7] N. Dasgupta, M. M. Scircle, and M. Hunsinger, "Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering," *Proceedings of the National Academy of Sciences,* vol. 112, pp. 4988-4993, April 21, 2015 2015.

[8] G. D. Vita, "Learning styles, culture and inclusive instruction in the multicultural classroom: A business and management perspective," *Innovations in Education and Teaching International,* vol. 38, pp. 165-174, 2001.

[9] B. M. Olds and R. L. Miller, "The effect of a first-year integrated engineering curriculum on graduation rates and student satisfaction: A longitudinal study," *Journal of Engineering Education,* vol. 93, p. 23, 2004.

[10] S. S. Courter, S. B. Millar, and L. Lyons, "From the students' point of view: Experiences in a freshman engineering design course," *Journal of Engineering Education,* vol. 87, pp. 283-288, 1998.

[11] D. W. Knight, L. E. Carlson, and J. F. Sullivan, "Staying in engineering: Impact of a hands-on, team-based, first-year projects course on student retention," *age,* vol. 8, p. 1, 2003.

[12] D. Kilgore, C. J. Atman, K. Yasuhara, T. J. Barker, and A. Morozov, "Considering context: A study of first-year engineering students," *Journal of Engineering Education,* vol. 96, p. 321, 2007.