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A New Change Model for Recruitment and Retention of Underrepresented Groups in STEM

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Abstract

Engineers tend to understand the world by making models. We design a model bridge and test it with heavy loads or put a model house through a simulated hurricane. We use Matlab to define a communications link and test it under various conditions with different input data. Our ability to draw accurate conclusions from these tests is tied directly to how good our models are.

When we think about women and underrepresented minorities in STEM, and how we are going to increase their numbers, the model that we typically use is that of a pipeline. The pipeline has shown up many times in papers from the psychology literature to ACM, IEEE and ASEE. This model has led us to suppose that the necessary approach to diversification is to work in the K-12 space to do more to fill the pipeline. But, in fact, for the last twenty years, there has been an army of ASEE members doing just that. And doing it well.

Then, when talking about women and girls, we came up with the idea of the "leaky" pipeline. Leaky pipes are repaired with duct tape. That means we just find the leaks and stop them up by having programs at key juncture points for young people. This model has shaped everything we do and led us to develop programs very much about getting kids excited and then providing them with the tools they need to weather the journey through the pipe. History has shown, however, a consistent deficit in the percentages of women and persons from black, native or Latinx origin.

There have been discussions of pathway models, highways with entrance and exit routes to account for transfer possibilities, but no model has led to any great epiphany that has effected great change. Women remain at approximately 20% of engineering students and underrepresented minorities around 10%.

What if this is the wrong model? It has led us to develop programs that apply "treatments" to the students and potential students, depending on our objectives. We essentially conduct programs with the aim of changing the students so that they will fit into the engineering world in one way or another, whether that is learning sufficient math or learning how to deal with bias and harassment.

Suppose, rather than a pipeline, we consider the diversification of STEM through the lens of a garden. This paper will discuss a new model that leads to different types of programming that can have a significant effect on increasing diversity and inclusion.

Introduction

In 2010, Heather Metcalf at UCLA published a critical review of the STEM workforce literature [1]. In her review she argues that several recurrent themes appear across the literature. These themes include a focus on the supply side focus, linearity, homogenization of people, view of people as passive, and others. In her doctoral dissertation, Alice Pawley adopted a "boundary" metaphor for talking about who does and does not belong in engineering [2]. She followed this up with an ASEE paper in 2011 with a critique of the pipeline model [3]. Among those critiques is that the "pipeline" metaphor does not allow for many of the lived experiences of women, and I would add, those of ethnic and other types of minorities in engineering as well.

The use of the pipeline metaphor in STEM areas may have simultaneously arisen in an article by Sue Berryman of the Rockefeller Foundation in 1983 [4] and a panel and study by the National Research Council: the Panel on Engineering Infrastructure Diagramming and Modeling and the Committee on the Education and Utilization of the Engineer[1], which was ongoing in 1984, with a publication produced in 1986 [5]. Berryman used the "educational pipeline" to examine the numbers of participants in science during high school and university education. The numbers were used to intuit causes for underrepresentation that closely align with the selected metaphor. The 1986 NRC publication appears to be the earliest use of the pipeline metaphor applied to engineering. A figure from the report[2] shows a complex pipeline model that even uses engineering-related piping conventions. Hilton and Lee looked at the SME pipeline (science, mathematics and engineering) as leaky at juncture points between transitions. Their primary focus, as was Berryman's, was to predict the numbers of participants in the SME workforce.

[1] Interestingly, the panel seems to have consisted of mostly men, with ten percent of the members being women.
[2] Reproduced with permission.

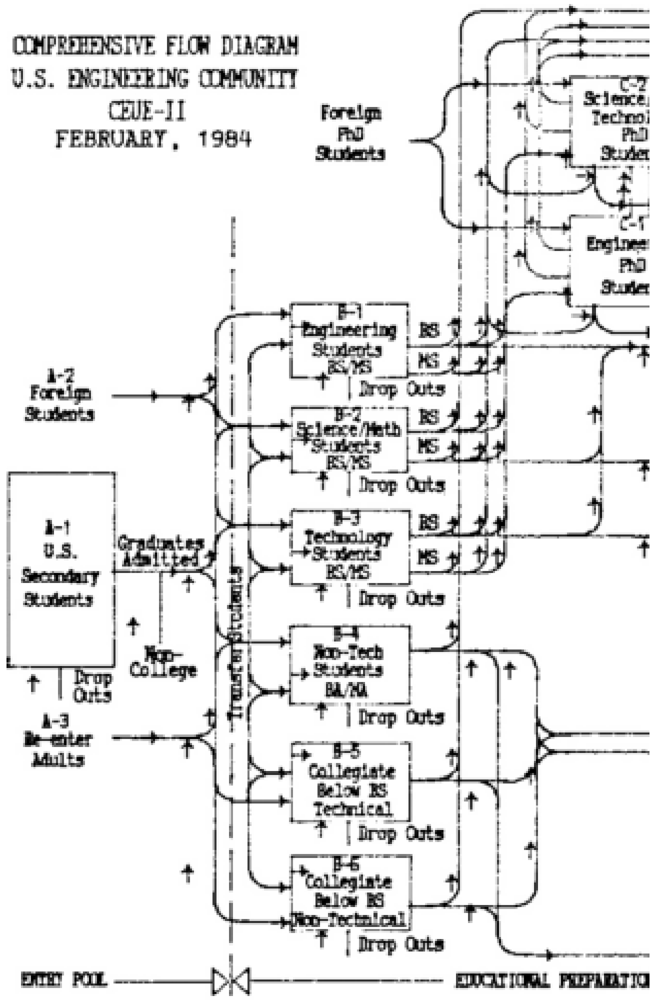

Figure 1: The pipeline flow diagram from the NRC report on Engineering Infrastructure modeling

The use of the pipeline metaphor has been more thoroughly documented in both Metcalf [1] and Pawley and Hoegh [3], both of which contain extensive lists of references. Some of the papers propose new models to replace the pipeline and some contain extensions or modifications of the pipeline model itself. The reasons given for suggesting alterations of the model are more uniform: to improve research and understanding on a variety of closely related topics, including recruitment and retention issues and diversity. Metcalf called this a "reliance on a flawed linear model that views students and workers as passive flows." Pawley and Hoegh even note that their critique of the model is not completely new, but that many engineering education researchers still rely on it without noting its limitations and their impact on any conclusions. Additionally, we might note that representation of women in engineering has not exceeded the low twenty percents, so we conclude that the current state of research hasn't had the effect that Berryman expected it to have in 1983.

A New Model and Its Application

Because the definition of insanity is doing the same things and expecting different results, it is time to pay attention to the critiques of this prevalent model. Additionally, it is time to pay attention to the decades of research on efficacious actions that correlate directly to increased recruitment and retention of a more diverse engineering student body and engineering workforce. The pipeline model, whether acknowledged or implicit as a part of research and practice, has restricted conclusion and action. A new metaphor will only be useful if it can lead to actions that have positive effects on the goals of increasing diversity and inclusion. In this paper we consider such a metaphor.

Suppose, rather than a pipeline, we consider the diversification of engineering through the lens of a garden. Before you plant a garden, you first prepare the soil. In our comparative model, this represents a very important point, which is to say that increasing the numbers of women and underrepresented minorities in engineering is best done, not by working to change the students, but by changing ourselves. The plan for a garden is laid out and anchor plants, maybe trees or bushes, are selected first. These plants need to be diverse themselves to ensure the overall health of the ecosystem. They serve as shade for seedlings not yet ready for full sun and even serve as a kind of existence proof themselves. The metaphor corresponds to a diverse faculty, which needs to be a deliberate part of a strategic plan, and *all* of the faculty need to focus on broadening participation. The ASEE Diversity Recognition Program [11], for example, includes attention to the diversification of faculty as a metric, but institutional commitment is best shown by inclusion of commitments in a publicly announced strategic plan. Hiring a diverse faculty may require that methods be employed akin to the approach of blind symphony auditions [12], for example, anonymous resume reviews. Implicit bias [13] shows up in every situation where the chance exists, so we need to design our procedures to minimize room for error. It is simply not true that diverse candidates who are superior are rare. O'Meara and Culpepper [14] compiled a list of proven practices as a part of an NSF ADVANCE program.

To diversify our garden, we will still seek out a variety of seeds. This doesn't change our K-12 efforts or the need to increase technological literacy among the general population. But the emphasis of our recruiting and our retention programs changes. A recruitment event becomes more about both seeming and being a welcoming, home-like place. A bridge program becomes more about networking and showing students ways to dig into the soil. Retention efforts focus on providing information and ideas to faculty, having workshops for teachers of entry engineering classes, and training TAs, than about hosting student seminars on how to succeed in classes. These things are akin to providing fertilizer and water and sunshine, while being sure that the plants in the garden are not overcome by weeds.

When we are planting seeds in a garden (or perhaps transplanting small plants, which represent transfer students), we do not examine each seed and decide whether it can make it in the garden. We plant it. If the seed doesn't sprout, it could be because the soil didn't contain what it needed or because it was watered too much or too little. Similarly, we need to release the assumption that some students just aren't cut out to be engineers. This perspective is based on the experience of those who already ARE engineers, and tends to perpetuate the status quo. There are many things that make a good engineer, and strength in mathematics is not the only one. Getting a C in physics and having to retake it doesn't mean that a student won't be a good engineer. Perhaps they need a little more fertilizer, because they came originally from a drought stricken area and weren't able to store enough energy.

Students have agency that provides them the freedom to make decisions about staying or leaving engineering, or re-entering it after a hiatus, that are not always the best. This is an important factor in how we design, implement, and even *name* programs. A recent student focus group at NC State University was very revealing. The students said that the emphasis placed on tutoring by the minority engineering programs made them feel like they somehow needed the tutoring more than majority students—or that we thought they did. For this reason, it is important to emphasize that ALL students benefit from tutoring. Another way to reduce perception of biased application of academic assistance it to provide a convenient place for students to gather, drink coffee and tea, and study together with a senior graduate student. It is more like providing a nurturing place for study rather than filling a deficit (which was more like the duct tape of the pipeline model).

Research [15] shows that linking material in class to actual practical applications, even through simple everyday examples, provides meaning that helps students process and appreciate what they are learning, perhaps even helping link the new information to internal models that they have in their own brains. Making students aware of when spatial visualization skills [16] are necessary to approach a problem can help them become aware of a hidden skill that many of us use without even being aware of it. Not understanding where their own skill level is and that they can learn to improve it, can lead to frustration and the decision to leave engineering, particularly for members of groups that suffer from imposter syndrome and the like.

In a garden, different plants need different conditions for their best growth. Some plants benefit from part sun/part shade, some cannot withstand full sun. In the garden metaphor, some students benefit from close proximity to mentors and advisors like living and learning communities and mentoring programs. At NC State University WMEP hosts a Tools Workshop to allow students to learn skills, like soldering, that they will need in laboratory and project work in a judgement free and community-centered atmosphere. Living and learning communities also provide sun and shade in the right mixes for students. Samuleson [17] is one example of how living and learning communities increase retention and academic performance for women in engineering.

There are also short day/long night plants like poinsettias and strawberries and long day/short night plants like lettuce and tomato. It is important to note that we used to try to force the plants to adapt to the circumstances in a one size fits all mentality. If a student didn't succeed, they were judged to just not be the right fit for engineering. Now we design our garden to fit the personality of our plants. The soil conditioning that is best for NC State University is not the same as that of Arizona State University.

To take things a step further, remember that plants have more needs than just soil. Water and a proper irrigation system are crucial to large scale gardening. In our model, this corresponds to the removal of barriers and red tape that might hinder the development of innovative ideas that can foster significant advancement. This can mean redesigning the curriculum, using every day examples in class and increasing faculty student interaction.

It turns out that good research supports these approaches. Engageengineering.org has research based resources for faculty about how to do a better job interacting with our students [18]. Research says that both the extent and quality of student interactions with faculty affect student performance and retention. The affirmation of a faculty person that they believe in a student's ability to succeed is like water to a thirsty plant, and it has a similar effect.

Even things that have been considered to be ancillary to engineering classes themselves, should cross pollinate the plants in the garden. For example, the Grand Challenges for Engineering are multidisciplinary and involve the social sciences as well [19]. This argues for the direct and intentional integration of liberal arts into both formal and information environments in engineering education.

Faculty and administrators also collect pollen from working with colleagues at other institutions and bring it back to enhance their own gardens. We rely on our fellow institutions to plant healthy gardens as well. Obviously this doesn't happen overnight, but over time, the garden can even become self-perpetuating as students graduate and go on to participate in gardening themselves.

Each of the practices suggested by the garden metaphor is proven through research. The joint application of those practices at NC State University has produced significant change over time. In 2015 the Wall Street Journal [20] noted stagnation in production of STEM workers. At NC State University this has not been the case. Figure 2 shows the trend over the last ten years for women in the first year engineering cohort. Figure 3 shows retention to second year by sex for each cohort, and figure 4 shows the six year graduation rate for students who start as first year students in engineering and complete in engineering. The total cohort size for each year is between 1400 and 1500 students.

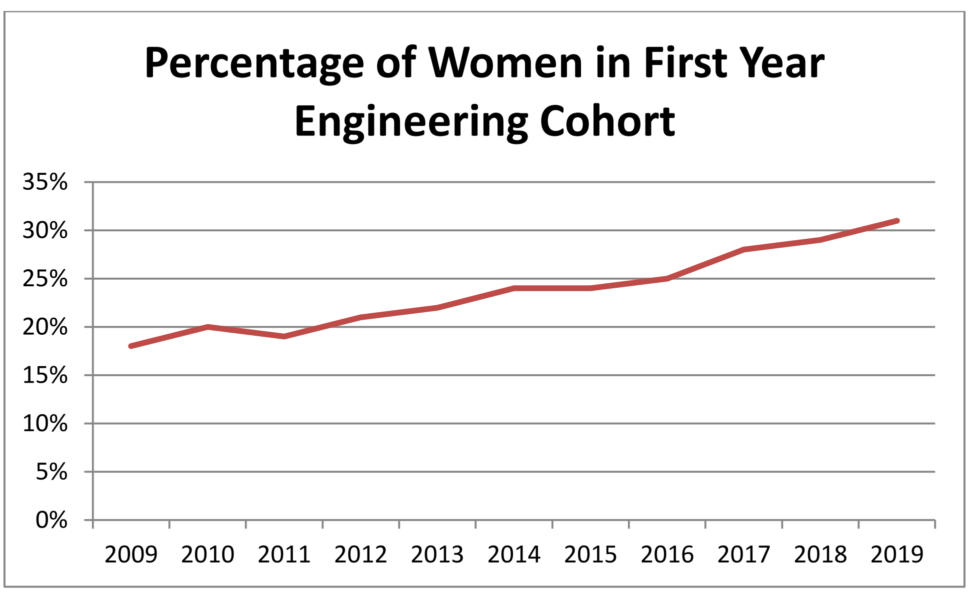

Figure 2: Women in first year engineering class over last ten years

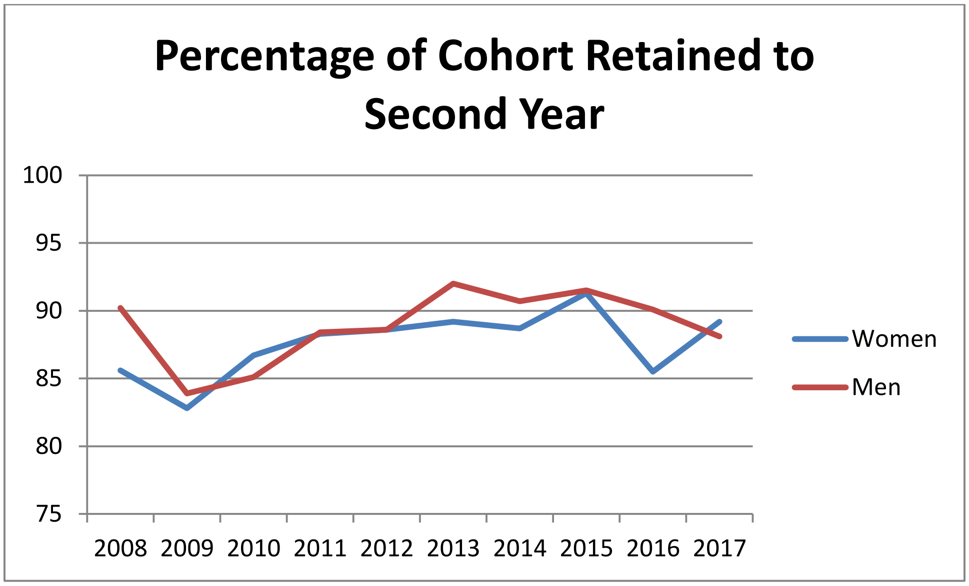

Figure 3: Retention to second year by sex of engineering cohorts

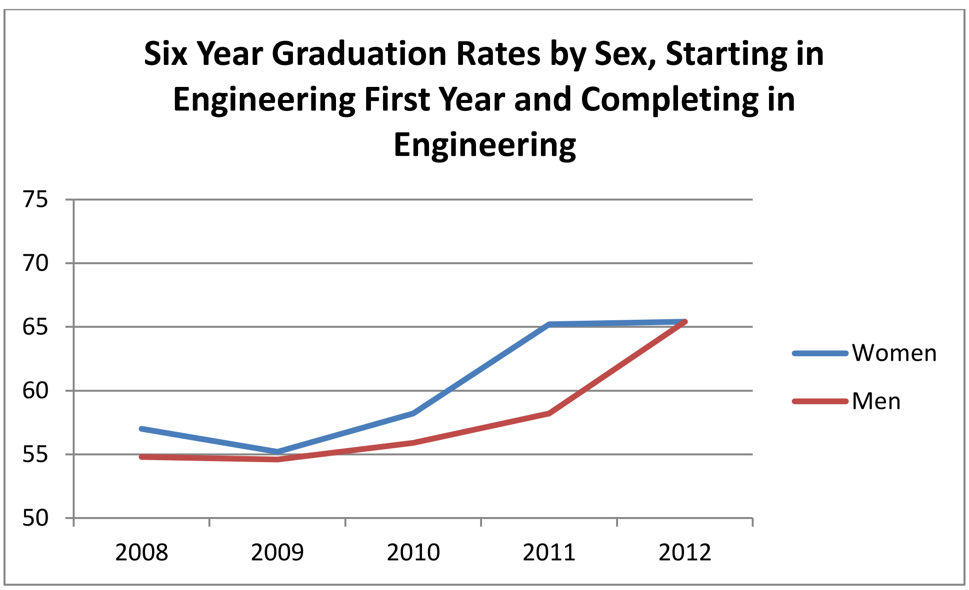

Figure 4: Six year graduation rates, engineering to engineering

The representation of women in each cohort has increased to well above the national average, while graduation rates for women in engineering have stayed above or equal to those of men. Although these numbers cannot be tied directly to the implementation of programs consistent with the new garden metaphor, they are the predominant changes that have been made during the indicated time periods. A paper by Susan Lord, et al., [21] shows how even in research using an ecosystem model leads to new ways of understanding the student experience. How much more so does this model help to develop new more effective practice?

Conclusion

The models we use drive directly how we think about problems and their solutions. Perhaps it is time to get rid of the model that we have used to no effect for 50 years and find a new way. A new model is a good way to start—a model that emphasizes making changes in ourselves to make room for diversity, not shaping the students we want to fit our existing mold. But this model must not be applied to the design of research exclusively, research that disappears into the ether and has no effect on practice. The dichotomy between research and practice must be bridged. What better place to begin that in the garden?

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