2018 CoNECD - The Collaborative Network for Engineering and Computing
Diversity Conference: Crystal City, Virginia Apr 29

Why Women Persist: Evaluating the Impact of Classroom-Based Interventions

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Dr. Kasi Kiehlbaugh is primarily interested in incorporating research-based pedagogical techniques into the undergraduate engineering classroom, and she focuses on employing active learning techniques and utilizing collaborative learning space classrooms. More specifically, her work examines how co-teaching, evolving classroom technologies, active learning in the classroom, and various classroom-based affective interventions targeted at fostering self-efficacy, belongingness, metacognitive learning strategies, and growth mindset affect various outcomes, including student retention and success, particularly during the freshman and sophomore years. Her field of research is undergraduate engineering education. Dr. Kiehlbaugh completed her BS and MS at the University of Arizona and her PhD at UC Berkeley. She is now an Associate Teaching Professor in the Chemical and Environmental Engineering Department at her undergraduate alma mater.

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Collaborative Network for Engineering and Computing Diversity Conference

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Kasi Kiehlbaugh and Paul Blowers

Introduction

Student retention in engineering, particularly of women, is often addressed through interventions that occur outside the classroom: through advising, mentoring, and the development of social support networks. However, this belies the fact that faculty members are the ones who have the greatest number of contact hours with students and therefore the greatest opportunity to retain women in engineering. Faculty play a unique and potent role because they are the ones who construct the activities, classroom environments, and assessments that so deeply affect students. The in-class experience is often lacking in important but subtle ways that can drive away capable students. Most faculty members are unaware of how they can redesign the educational experience to enable students to succeed. Unfortunately, this inattention represents missed opportunities to retain more women, underrepresented minorities, and first-generation students in engineering.

Modern university classroom experiences are often cold, impersonal, and demotivating. Students in entry-level engineering courses are still transitioning from supportive high school environments in which they were personally known by their teachers and peers into the sink-or-swim world of higher education. To address this, our approach has been to reverse-engineer classroom interventions that have led to a dramatic increase in student retention in our own chemical engineering program. Nationally, retention in engineering through graduation is approximately 30-55% [1], [2]; the average University of Arizona College of Engineering retention rate through graduation over the past 5 years is 46%. Through the deployment of a variety of classroom-based interventions throughout our sophomore-year courses over the past 2.5 years, we have increased the retention through graduation to 70% within our Chemical and Environmental Engineering Department.

We have achieved this dramatic increase in retention by iterating through several years of intervention development and deployment. *Crucially, our interventions combine elements designed to affect students across a range of affective learning categories—an approach not yet found in the literature*. However, while we have anecdotal information from students regarding their responses to many of the interventions, we have not yet scientifically studied which interventions are important to which student populations. This paper will thus describe successful practices that we have implemented, highlighting those that are thought to have the largest effect on women based on a combination of the literature and relevant survey responses. Our future work will involve rigorously evaluating our interventions to determine which interventions are most effective in supporting female engineers to graduation as we pursue our long-term goal of empowering students to take charge of their own learning and persist to graduation.

To support dissemination of the results to our colleagues, we have established a faculty learning community within the College of Engineering to reflect on teaching methodologies, share best practices, and conduct peer observations. As we measure which interventions are most effective in supporting female engineers to graduation, we will have an immediate cohort of engineering instructors with whom we can deploy the interventions and scale up across the College of Engineering.

The Approach

Although we arrived at a set of scalable and cost-effective interventions through iterative experimentation in the classroom, each of the interventions are grounded in three well-understood affective learning categories—belongingness, self-efficacy, and metacognition.

Extensive measurements show a correlation between student persistence and feeling connected to others—their sense of *belongingness* [19] – [21]. Students who feel disconnected from their peers, major, or institution will often leave; this is particularly true for women, transfer students, and underrepresented minorities [22], [23]. While many studies measure belongingness, few report interventions that attempt to bolster it, and if an intervention was performed, it was not carried out in tandem with self-efficacy or cognitive interventions.

Self-efficacy is "one's belief in one's ability to succeed in specific situations or accomplish a task [3], [4]." Many measurements highlight the link between high academic self-efficacy and successfully completing college degrees [5], [6]. The evidence is particularly strong in STEM fields [7] – [9]. Published self-efficacy studies are primarily diagnostic in nature and show that students, particularly women and underrepresented minorities, leave STEM fields *even before their academic performance falters* if their self-efficacy is low. Few interventions designed to enhance self-efficacy have been conducted in STEM fields; of those published, results were mixed and not scalable due to cost and time constraints [10]. Our classroom interventions address each factor affecting self-efficacy that was identified by Bandura—mastery experiences, vicarious experiences through modeling, social persuasion, and physiological factors—and are expected to increase self-efficacy.

Finally, applying *metacognitive approaches to learning* in the classroom familiarizes students with learning strategies and gives them concrete practice using them [11], [12]. Research shows that students fail to select effective learning strategies when challenged because of faulty (or missing) knowledge regarding how learning occurs. People either believe that their academic abilities are fixed and cannot be changed (a *fixed mindset*) or that abilities can improve through effort (a *growth mindset*) [13].

The first step to changing one's learning practices is to adopt a growth mindset. We intentionally foster growth mindsets in our students in a number of ways: (1) by explicitly discussing the concept and describing the benefits of adopting a growth mindset; (2) by modeling a growth mindset in our own lives, which means sharing growth-oriented thoughts on our own failures and challenges with students; (3) by breaking up classroom calculations into microtasks that allow students to experience repeated small successes over time; (4) by praising efforts and strategies rather than intelligence; and (5) by designing classroom activities that are cooperative rather than competitive or individualistic. After students have shifted to a growth mindset, faculty can show students how to influence learning outcomes by applying metacognitive learning strategies [14] – [17]. Research to date reveals that deploying these techniques can help students [18], but most studies were conducted in laboratory environments, and none were performed concomitantly with self-efficacy or belongingness interventions.

The Interventions

Though we employed universal design as we developed the interventions to increase the retention of all students, here we describe those interventions that we believe are—based on informal feedback from

female students—most effective at improving the retention rate of undergraduate women in engineering. There are three in particular that have had a significant positive impact:

1) assigning formal teams that include at least two women;
2) employing instructional language that fosters a warm and inviting atmosphere and focuses on mastery experiences rather than performance goals; and
3) actively knowing and using individual names and personal details throughout the course.

Note that while these interventions were employed in a classroom set up to facilitate collaborative and active learning, they could be employed in any type of classroom by instructors using a more traditional lecturing approach.

It is known that underrepresented minorities often feel less integrated into classroom culture [22] and that women tend to drop out if they lack social support or self-confidence [22], [34]. Conversely, students with greater social support are less likely to think about transferring [35], and women specifically benefit from access to support networks [23]. Thus, the first key intervention for women involves fostering belongingness through assigned formal teams that are rotated throughout the semester, always ensuring that at least two women are present on any team with female members so they cannot be marginalized. Dissolving the teams after each midterm exam and forming new ones builds a networked community that accelerates the formation of social ties [24] and student belongingness within the cohort.

This practice of formally constructing teams has been shown to foster the development of peer support [1], [25], encouraging students to persist [26], [27]. Social networks have been shown to help in overcoming life crises (e.g., the loss of a key support relationship), a common reason for students to withdraw from challenging STEM programs [28]. Formal groups facilitate close interpersonal relations with other students [21], and individuals in supportive interpersonal relationship are buffered from and more resilient to stress [29], [30]. Social integration, in turn, increases how readily students work with peers within an academic context [31]. A community of learners increases positive behaviors and positive emotions [32], and networks of support help students learn [13], [33].

Forming teams with at least two women on each team is crucial because this practice increases belongingness and fosters vicarious successes [36]. It has been shown that intentionally organizing the environment has a large effect on groups vulnerable to threat—gender balance matters a great deal [37], and there is less perceived bias when women equal or outnumber men [38].

A second key intervention for women involves conscious, intentional use of self-efficacy-promoting language by the instructor, coupled with avoidance of language that would create a 'chilly climate.' Direct encouragement from the instructor influences self-efficacy through the social persuasion factor. Following are some examples of types of self-efficacy-promoting language we use with our students: (1) explicitly stating that we believe every student in the class is capable of mastering the content and succeeding in the course if they are willing to put in the required effort, (2) verbally acknowledging their successes in being admitted to the university and being accepted into the engineering program, and (3) encouraging them to reflect on their own beliefs about their ability to solve a given in-class problem both as an individual and as a team.

To avoid creating a chilly climate, it is particularly important to avoid language that is sarcastic or ridiculing [1]. This type of language discourages participation and creates an atmosphere of intimidation. Women are attracted to and tend to persist in majors that have a warm and inviting feel [36]. Even unintentional microaggressions such as repeatedly interrupting someone can alienate marginalized students.

Using language that focuses on mastery experiences as opposed to performance goals (e.g., understanding the content vs. earning an A) increases self-efficacy and motivation [39], [40]. Mastery-oriented individuals are more focused on the process of learning and are thus better able to maintain skills and have more positive emotions [39]. Students with low self-efficacy show increases in performance when a mastery orientation is stressed [39], and mastery goals lead to deeper processing and learning strategies [41]. Following are some examples of language we use that guides students to focus on mastery experiences: (1) encouraging students to get excited about failure, to see it as feedback that more effect is required and as an opportunity to uncover hidden assumptions and develop a deeper understanding of the topic as a result; (2) placing the emphasis on understanding concepts rather than ending up with the right number at the end of a calculation; and (3) acknowledging that learning occurs at different rates, even for the same person in different situations, and that the rate at which one learns something has no bearing on the eventual mastery of the task.

The final key intervention for women involves knowing students' names and a bit about them. Learning student names and personal details fosters belongingness: recognizing individuals establishes a spontaneous personal connection with the instructor, and the mere act of being noticed can even create a moment of pride in the student. It has been shown that personal interactions with faculty are critical to success [16]. Warm interactions between students and faculty lead to higher self-efficacy [21], [42], [43]. High levels of faculty concern lead to the best classroom experiences for students [44].

We have noted very strong positive responses from students when we as instructors show up on the first day of class knowing everyone's name on sight, even in a class of over 100 students. To accomplish this task, we download our course photo roster from the university's digital instructor center and then import the names and pictures into a flashcard app. The app has several spaced repetition modes that allow you to focus more on the cards you miss. With this tool, short intervals of otherwise unproductive time, such as waiting in line at the store, can be used to learn names and create opportunities to connect in a personal way with students.

These examples are representative of the types of interventions we have developed and deployed within our classroom. The interventions are low cost and can be deployed in nearly every discipline, at every level, and regardless of which instructional modes are being used (active learning, lecture hall, or online classes).

Future Work

While we presently have anecdotal, self-reported information from students regarding the interventions described here (as well as many others), we have not scientifically and rigorously studied which interventions are important to which student populations or have the most significant impact on particular outcomes. Our future work will explore these open questions. Using funding recently obtained from the Engineering Information Foundation to study the impact of our interventions on women, we will be analyzing preliminary data from an unfunded pilot study conducted during Fall 2017

and Spring 2018. We intend to develop and deploy comprehensive, validated survey instruments covering all interventions that we deploy in our classroom. The validated instruments will be deployed in Fall 2018 and used to fill in the gaps in the data that are identified from the first analysis. We anticipate that the focus group data will reveal areas that need to be probed with more specific questions.

Another important objective for our future work is to deploy selected interventions in other engineering courses in collaboration with colleagues in our engineering faculty learning community (FLC). The inspiration to form the group came from the success of the FLC model that has been employed university-wide at the University of Arizona for several years to foster culture change among faculty. The campus-wide FLC groups focus on learning about and experimenting with evidence-based teaching practices. The engineering FLC group, formed in Summer 2017, began an engineering-centered discussion about improving student success and retention in core engineering courses. Nine faculty from across the college met every other week over the summer, with an additional five faculty joining the group during the fall semester.

Using *Teach Students How to Learn* by Saundra McGuire, the engineering FLC experimented with some of the learning techniques ourselves and discussed how to deploy those with students. We talked about how to foster a sense of community among students and how to improve their confidence in their engineering abilities. The Dean of the College of Engineering provided a small participation stipend of $500 each to encourage faculty to participate and is continuing to support the group in 2018 with philanthropic funding. In addition to the financial support from the Dean, we are pursuing external funding to support the transfer of the most impactful interventions to other disciplines.

A final area of our future work regarding the retention of women in engineering will involve investigating the role of classroom role models. How important is it that young women pursuing engineering have female instructors, graduate teaching assistants, and undergraduate preceptors that they can look up to as role models? Anecdotal evidence from female freshman engineers indicates that having a female instructor in their first engineering course mattered a great deal to them and helped them envisage their own success in their chosen field.

Conclusion

Few interventions are described in the literature that improve student retention; of those performed and reported, nearly all are applied outside the classroom—and none of them address dynamics simultaneously across all three affective learning categories. Because faculty members are the ones most in control of student successes and experiences surrounding learning, it is necessary to change faculty behavior in the classroom such that we are creating an environment conducive to learning and success for all students. The three simple interventions described here are inexpensive to implement, readily scalable, and have been shown anecdotally at the University of Arizona to increase the retention of women in engineering and to improve their grades by addressing the primary reasons women leave engineering.

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