Adding Diversity and Culture to the Engineer's Toolkit: Evaluating a Unique Course Option for Engineering Students

Ms. Chelsea Nneka Onyeador, Stanford University

I am a 4th year Mechanical Engineering B.S. student at Stanford University, planning to pursue graduate work in Aeronautics and Astronautics at MIT next year. I am a Nigerian-American from central Texas, and I am a devoted advocate for diversity in engineering.

Dr. Shannon Katherine Gilmartin, Stanford University

Shannon K. Gilmartin, Ph.D., is a Senior Research Scholar at the Michelle R. Clayman Institute for Gender Research and Adjunct Professor in Mechanical Engineering at Stanford University. She is also Managing Director of SKG Analysis, a research consulting firm. Her expertise and interests focus on education and workforce development in engineering and science fields. Previous and current clients include the American Chemical Society, the Anita Borg Institute for Women and Technology, California Institute of Technology, the College of Natural Sciences and Mathematics at California State University Fullerton, the Office of the Vice Provost for Graduate Education at Stanford University, the School of Medicine at Stanford University, and the School of Fisheries and Ocean Sciences at the University of Alaska, Fairbanks.

Dr. Sheri Sheppard, Stanford University

Sheri D. Sheppard, Ph.D., P.E., is professor of Mechanical Engineering at Stanford University. Besides teaching both undergraduate and graduate design and education related classes at Stanford University, she conducts research on engineering education and work-practices, and applied finite element analysis. From 1999-2008 she served as a Senior Scholar at the Carnegie Foundation for the Advancement of Teaching, leading the Foundation's engineering study (as reported in Educating Engineers: Designing for the Future of the Field). In addition, in 2011 Dr. Sheppard was named as co-PI of a national NSF innovation center (Epicenter), and leads an NSF program at Stanford on summer research experiences for high school teachers. Her industry experiences includes engineering positions at Detroit's "Big Three:" Ford Motor Company, General Motors Corporation, and Chrysler Corporation.

At Stanford she has served a chair of the faculty senate, and recently served as Associate Vice Provost for Graduate Education.

Dr. Gloriana Trujillo, Stanford University

Gloriana Trujillo joined the Office of the Vice Provost for Teaching and Learning at Stanford University in 2015. She initially trained as a basic science researcher, having first earned a B.A. at Dartmouth College in Biology, followed by a Ph.D. in Biological Sciences from the University of California, San Diego. Gloriana became interested in teaching and learning through her graduate work as a developmental neurobiologist and was awarded an National Science Foundation GK-12 Fellowship. She became intrigued by pedagogical approaches and how these impact students in the biology classroom during her National Institutes of Health-funded IRACDA Postdoctoral Fellowship at the University of New Mexico. Gloriana's interest in biology education research led her to San Francisco State University, where she worked with Dr. Kimberly Tanner on biology department-wide faculty professional development funded by the Howard Hughes Medical Institute. At SFSU, Gloriana's research sought to understand students' self-efficacy, sense of belonging, and science identity to ultimately affect change in undergraduate biology classrooms. Throughout her scientific career, Gloriana has been an advocate for underrepresented and underprivileged populations, and is an active member of SACNAS.

Dr. Carol B. Muller, Stanford University

Carol B. Muller is the Executive Director of WISE Ventures, an internal initiative at Stanford, designed to communicate, build networks, and help seed new and needed ventures across the Stanford campus to

advance gender equity in science and engineering. She also directs Stanford's Faculty Women's Forum. A longtime university administrator, educator, and social entrepreneur, her past experience includes service as Associate Dean for Thayer School of Engineering at Dartmouth College, where she co-founded the campus-wide Women in Science Project. She founded and was chief executive of MentorNet, a large-scale online nonprofit global mentoring network advancing diversity in engineering and science (1996-2008). At Stanford, she was consulting associate professor of mechanical engineering between 1998 and 2002, collaborating with faculty and staff to create "New Century Scholars: Teaching, Learning, and Your Academic Career," a summer workshop designed for new engineering faculty members. A Fellow of the Association for Women in Science, Dr. Muller and her work have been recognized with other national awards, including the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring, and the Anita Borg Social Impact Award. She has authored and presented numerous papers, presentations, and workshops. She earned an A.B. from Dartmouth in philosophy (1977), and A.M. (1981) and Ph.D. (1985) degrees in education administration and policy analysis from Stanford, and continues to build upon research in the design and implementation of programs.

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Abstract

Lack of diversity in engineering is a persistent problem at both industry and collegiate levels. Defined for this paper as individual qualities divergent from historical characteristics (or even stereotypes) of engineers, diversity, at times, seems to be at odds with the culture of engineering itself. Lack of diversity in engineering manifests in a decreased retention rate of underrepresented minorities and women pursuing engineering degrees and engineering careers, a culture of homogeneity in engineering education and professional practice, and ensuing limitations to engineering design and product development. A more diverse engineering enterprise, by contrast, increases inclusivity and can provide a competitive advantage in industry [1].

One potential solution to this problem is the integration of diversity education into engineering curriculum at the undergraduate and graduate levels. Diversity education here includes courses addressing the culture and social context of engineering, the disparate outcomes of engineers belonging to groups traditionally underrepresented in engineering, and inclusive engineering practice. Courses such as these would help students contextualize their experiences and those of others in a larger body of knowledge about human interaction, challenge implicit biases, and make a statement about institutional values of inclusion. These courses may align with a larger movement in engineering education to integrate ethics, human-centered design, leadership development, and community-based project work—considerations of people, in other words—into more traditional technical coursework [2] - [5].

This paper examines one such course offered at Stanford in 2017 as both a case study and reflection opportunity. This paper is authored by a student who was enrolled in the 2017 course, with the collaboration and co-authorship of the course instructors. Together our work relays the course experience from a first-hand perspective (through the experience of the lead author) and evaluates several course aspects, including its impact and efficacy (through instrumentation developed by the instructors and by the institution and administered to all students in the class). We share recommendations for course improvement, and for related curricular efforts in engineering, based on both student reflection and evaluation data. Our analysis and recommendations focus on inclusivity, which is the ability of students of all backgrounds to engage meaningfully with the course. Since the goal of such courses is to attract students with a range of experiences and backgrounds, inclusivity in every course component is critical.

I. Introduction

It is well documented that today's engineering students, faculty, and practitioners in the U.S. do not represent the demographic profile of the national population [6]. While a strong argument in favor of diversity based on social and demographic group membership can be made on the

grounds of fairness, there is another, perhaps more compelling argument to be made. William A. Wulf captures that argument when he states "…sans diversity, we limit the set of life experiences that are applied, and as a result, we pay an opportunity cost - a cost in products not built, in designs not considered, in constraints not understood, in processes not invented" [7]. In addition to technical skill and depth of knowledge, engineering requires creativity, interpersonal skills, "life experience", and closer connection to those experiences to most effectively meet societal needs. The sheer scale of work now—globally distributed, with headquarters in one country, fieldwork in perhaps another, technical developers in still a third (e.g., Hinds et al. [8])—demands engagement with diversity, the meaning of difference, and communication across cultural boundaries. For these reasons, it is imperative to consider the capacity of engineering education to improve the non-technical, diversity-related skills of engineers, which include the ability to consider and incorporate culture and diversity when solving engineering problems.

Curricular and co-curricular efforts towards this end are the subject of study and debate, even as there is recognition of the range of skills, technical and non-technical, required by real-life engineering (see [2] and [9]). Few of these efforts, however, squarely place culture and diversity as the central topic of investigation, leaving general education requirements at a given institution to "do the job" of connecting engineering students to the largely social science-based scholarship on diversity, culture, interpersonal interactions, organizations, and institutional change. There are exceptions, perhaps even increasingly so; these "exceptional" courses may be seen as part of a larger movement in engineering education to integrate ethics, human-centered design, leadership development and community-based project work—considerations of people, in other words—into more traditional technical coursework [2] - [5].

At the center of this paper is one such course newly offered at Stanford in the winter term of 2017. The name of the course was ENGR 311C/FEMGEN311C Expanding Engineering Limits (EEL): Culture, Diversity, and Gender. The course was developed to address a curricular gap in the school of engineering: the absence of an engineering-based formal learning environment that directly investigated issues of culture and diversity in engineering knowledge, design, education, and industry practice. This paper uses case study approaches, course evaluation data, and firsthand student reflection to assess the course offering—only the second in its short timeline. The paper addresses the following questions through the perspectives and feedback of students taking the course:

- How did this course differ from more "traditional" engineering courses?
- What were the overall outcomes of the course?
- What were the most effective practices and pedagogies employed in this course?
- In what ways was the course successful? In what ways could it be improved?

The paper concludes with a commentary on the course's relevance for engineering faculty who are considering these types of learning experiences, and industry professionals who are recruiting

engineering students into their workplaces. Potential directions for future research are discussed as well.

In this paper, we use a combination of the lead author's firsthand experience and course evaluation data collected from a broader range of students taking the class to speak to the course features, lived experience, and outcomes. As such, portions of this paper will be recounted in the first-person perspective of the lead author, and other portions adopt a more traditional third-person narrative structure. We intend for the results to shine a new light on curricular efforts to engage engineering students with culture and diversity topics in their own engineering contexts and inform similar efforts to realize a more diverse engineering enterprise through education for the benefit of all.

II. Course Background and Description

As the name of the course implies, EEL differed from more traditional engineering course in that it was not focused on technical engineering skills, but more on the social aspects of engineering. EEL was cross-listed in both the School of Engineering and the School of Humanities and Sciences as a Feminist Studies (FEM) course. The course was focused around a single question: *"How do culture, diversity, and gender shape who chooses to become an engineer, which problems are solved, and the quality of designs, technology, and products?"* [10]. The course had 3 main learning objectives: (1) Identify and analyze the interdependencies of gender, diversity, culture, and engineering, using a variety of methods; (2) Connect issues relating to gender, diversity, and culture to students' experiences in college and future workplace experiences; and (3) Envision new engineering processes, practices, and cultures that reflect expanded perspectives on gender, diversity, and intersectional identities [10].

This course was developed over a multi-year period and first launched at Stanford in the 2015-16 academic year, in partnership with Aachen University in Germany. The first course was taught synchronously at both sites and students worked on cross-Atlantic project teams. A total of 20 Stanford students enrolled, alongside 15 students from Aachen. In the second offering of the course in Winter 2017—the focus of this paper—EEL was a parallel course to University Y's course (taught at a different time of the academic year, due to differing institutional calendars and scheduling constraints). Several changes to the course were made on the basis of students' feedback to the first offering. Thirty-three students completed EEL in 2017, and several continued in a companion project courses in the following academic term to develop new tools to better include diversity, gender and culture in engineering education and design (this paper is the result of one such project-based independent study by the lead author). With funding support from Stanford's administration, EEL during the 2016-17 academic year also was part of a "Faculty College" that, in addition to the teaching staff, engaged approximately 13 faculty participants from across the university, in departments and programs including engineering, education, feminist studies, history, psychology, sociology, and student affairs departments and programs [11]. (At the time of this writing, EEL is currently in its third offering (Winter 2018)).

EEL is unique in that only a few courses like it exist today. Levine conducted a preliminary study of similar courses offered at post-secondary institutions [12]. While her search was neither exhaustive nor global in scope, her findings suggest that there exist few courses relating to culture and diversity in engineering in U.S. universities, and of those courses, many have a narrower scope than EEL, often times focusing specifically on gender.

This class was marketed as having the potential to fulfill the Technology in Society requirement for engineering students but offered no other external incentives to take the course beyond the two units for which it was listed. Students were expected to attend class meetings but could miss two classes without penalty. EEL was open to graduate and undergraduate students across the university. The vast majority of those who enrolled in the course were students who were majoring in engineering.

Structure

The overall structure of the course varied from class to class (with 20 sessions in total given Stanford's quarter-based academic calendar). Some sessions would begin with a warm-up activity, continue to a longer activity followed by a discussion, and end with a wrap-up in the form of short "one-minute" papers [13]. The specific activity completed during the class session varied, ranging from a "data dive" into the American Society for Engineering Education (ASEE) online engineering college profiles [14] to "I Like, I Wish" worksheets centered on cultural change. Other times the class would begin with a brief introduction by one of the instructors that was then followed by a lecture from a guest speaker (see below) and then by a Q&A session.

Each session lasted for 80 minutes. The class was scheduled relatively early in the morning, 9 am, so breakfast pastries and coffee were occasionally offered by the teaching team. The class was relatively small with only 33 students. Students sat in groups of 4-6 across seven tables.

The course was organized into two major sections: (1) defining terms and theoretical and conceptual frames for investigating culture, diversity, and patterns of underrepresentation in engineering (e.g., "gender", "intersectionality", "stereotype threat"), and (2) case studies on how culture, diversity, and gender influence engineering knowledge and design, academic experiences, and industry practices/workforce experiences.

Reading Material

Each week, students were assigned a few short readings. These readings were to be read on the students' own time and most were accompanied by questions for reflection and response. These reading responses were short, sometimes as brief as only a few sentences, and were to be submitted online before the first class session that week. Instructors gave individualized feedback on those responses. The readings were from many sources: journals, magazines, academic studies, blog posts, company websites, etc.; and covered various topics related to diversity in engineering from multiple perspectives. These readings included Cech and

Waidzunas's research on LGB students in engineering fields [15], Smith and Lucena's research on low-income first-generation college students in engineering [16], Cheryan et al.'s research on "ambient belonging" in computer science [17], and Fouad and Singh's work on factors that explain why women leave the engineering workforce [18]) .

Pedagogical Techniques

There were numerous pedagogical techniques utilized over the duration of this course. Students were assigned to table groups, in contrast to most university learning environments engineering students more usually experience, and asked to discuss sets of questions, ideas, or concepts. This approach was used in an attempt for students to interact with students they otherwise would not. It was not until the last few weeks of the quarter that students were allowed to choose with whom they sat and thus discussed. At the beginning of the quarter, students developed group norms meant to provide guidelines for open and productive discussion. The discussions held in these groups were often heavily facilitated by the questions they were assigned to discuss. Other times, students were given more freedom to talk about more open-ended questions.

The course material was covered through a combination of readings, lectures, in-class activities, and out of class assignments. Students' final grades (the course was offered on a pass or no credit basis) were based on attendance, in-class participation, and assignments including reading responses (described above), a photo project, conversation projects, and reflection papers. These assignments differed from typical engineering assignments as they were not meant to assess technical skills. Instead they asked students to investigate the cultural artifacts of engineering using methods more common in social science.

Students completed a photo project as one of the first assignments of the quarter as an introduction to the concept of engineering culture. For the photo project, students took pictures of where they worked on engineering problems, and then a class discussion was held about the pictures they took. The photo project contextualized engineering culture by illustrating engineering spaces from a student perspective.

Conversation projects were intended to reinforce course learning objectives by having students address topics in the class with people outside of the course community. In this set of assignments, students were given prompts related to material covered in the course (e.g., "When you think about engineering culture(s), how would you describe it? What words come to mind? What images?", and "When you think about how products are conceived, designed, and implemented or manufactured, in which ways do you see gender and race playing a role or influencing these processes?") and asked to hold conversations with other students not enrolled in the course to glean information about what other Stanford students thought about those topics (questions could also be asked of other faculty and staff at the university, or even people outside of Stanford altogether). Students were not required necessarily to use the questions they were given, as the exercise was meant to be a conversation rather than an interview. Students were

asked to hold these conversations on their own time outside of class and then issue reports, first to their discussion groups and then to the entire class. The conversation projects were assigned multiple times during the quarter. These conversation assignments were developed by the course teaching assistant, inspired by his residential education experiences at the university, and his experiences leading design thinking exercises in other classes.

Students also were assigned two reflection papers. The first reflection paper was due the fourth week of the quarter and the second paper was due finals week (week 11) of the quarter. The purpose of the reflection papers was to encourage students to think about engineering culture in terms of what it is, and what it could be if diversity was more systematically and deeply taken into account (students also were asked to select *existing* practices in engineering that actually benefited or worked to the advantage of realizing such cultural change). For the reflection papers, students were asked to write a few pages discussing one facet of engineering culture that could be improved, according to the teachings of the course (e.g. improving ambient belonging [17] or appreciating diverse funds of knowledge [16]). The second reflection paper was slightly longer than the first and provided students the opportunity to either elaborate further on the ideas from their first reflection paper or to address a new idea entirely, and address possibilities and strategies for change more directly. Students also had the opportunity to receive feedback on their papers from both the teaching staff and their classmates.

Guest Speakers

Roughly every other class, guest speakers were present to give lectures related to the week's topics. These guest speakers were chosen because of their relevant background and experiences. Some of these speakers were authors of class readings. The speakers had various backgrounds including industry professionals, university administrators, university students, HR representatives, and professors. Several of the speakers were not Stanford affiliated and some came from other parts of the country to speak.

III. Analytic Methods for this Paper: Evaluation Data Analysis and Lived Experience

Our goal for this paper is to analyze EEL through two lenses: 1) course evaluation data collected from all students and 2) lived experience of the first author. We conceive of the analyses in this paper as a "case study" in some sense. The methods used in this paper are reminiscent of the methodology described by Creswell, Hanson, Clark, and Morales [19], but our overall approach is less formal. We see our setting as one example, a case, of curricular efforts in engineering to integrate individuals and communities more strongly into everyday technical practice. Our paper is descriptive, with multiple levels of analysis (viewpoints of a single student, and aggregated evaluation data).

However, we also conceive of our analyses as a critical reflection opportunity for members of our course community. The overall structure of the paper weaves together a case-study feel and significant reflection, resulting in, we hope, a richer picture than could be provided in either

scenario on its own. The methods used in this paper were approved by Stanford's Internal Review Board.

Course evaluation data

The teaching team for EEL collected feedback on the course both over its duration and after the course was completed. Evaluation methods were varied; for the purpose of this paper, the focus is on de-identified aggregate data from the course's voluntary "pre" and "post" surveys (designed by the teaching team), as well as from the "official" course evaluation form administered by Stanford to all students and classes. The voluntary "pre" survey, also known as the Calibration Survey, was assigned the first week of the course, and the "post" survey, or the Recalibration Survey, was assigned during the final week of the course. Responses were submitted for several weeks afterward. For both Calibration and Recalibration Surveys, students were asked open-ended questions and fixed-choice questions, which were generally measured on a five-point response scale (see Table 1).

Table 1. Likert Scoring used for Calibration and Recalibration Surveys

Score	Value
1	Not interested/confident
2	Slightly interested/confident
3	Moderately interested/confident
4	Very interested/ confident
5	Extremely interested/confident

Note: For one set of confidence questions, students were presented with a sixth response option: "Not sure". No student in the sample for our analyses marked this option.

Each survey question fell within one of three categories: *questions gauging **interest**, questions gauging **confidence** in one's ability to perform specific actions*, or *questions gauging **confidence** in one's ability to describe in conversation with friends topics related to the class*. In keeping with the pre/post design, the same set of questions were asked both at the start of the course and at the course's completion; however, a much smaller subset of students completed the recalibration survey (as the quarter came to a close, students left for spring break, and new classes started in spring quarter). Drawing from the anonymized data, and employing paired sample t-test techniques, we analyze average scores on survey items among the 12 students who completed both the Calibration and Recalibration Surveys. These data are reported in the next section.

Student feedback also was collected through a routine process at the university and occurred at two points during the quarter: mid-quarter student feedback and final course evaluation. For mid-quarter evaluations, third-party administrators collected feedback somewhat informally. Instructors were asked to leave the room and students discussed freely with each other and the administrators. This feedback was centered around the class format and the content itself. The

feedback at the end of the quarter was collected through an online course evaluation form. At the end of every course, Stanford students are asked to submit course evaluations, evaluating various aspects of the course, including teaching staff, curriculum, and workload. This evaluation is then published for both students and instructors [20]. With 28 of 33 students participating in at least some portion of the end of quarter evaluations, this feedback was more representative of the larger class than were the Calibration and Recalibration surveys. The results of these surveys are also included in the next section.

IV.1 Course Outcomes: Evaluation Data

To begin our consideration of course outcomes, successes, challenges, and opportunities for the future, Table 2 summarizes data collected from students on the Calibration and Recalibration Surveys. There are several features of this data that are important to note, the first being the relatively small sample sizes. Neither survey was compulsory. As a result, not all students completed the survey. Of the 33 students enrolled, 23 completed the survey at the start of the course, and 13 completed the final survey (we suspect that end-of-quarter voluntary surveys are more difficult for students given their final exams and projects, and personal investment in the course may have declined by the time students began the next term). The longitudinal pre/post sample is composed of 12 respondents—about one-third of the total course community. Thus, this sample is not necessarily generalizable to all students in the class. It is also important to keep in mind that these data are self-reported, and we cannot definitively speak to student's "actual" abilities, only to their confidence in their abilities, their interests in course topics, and what "confidence" and "interest" might signify. However, there are still some interesting trends we can comment on for this case study.

Perhaps the most apparent trend is that when students were asked to rate their confidence in their abilities, the mean scores increased after taking EEL, meaning that after taking the course, students had become more confident in their ability to address the topics covered in the course. Confidence is a domain that is relevant to EEL, insofar as confidence can be critical to one's sense of agency in the world [21], which maps onto our second and third learning objectives (connecting course topics to one's own pathway and envisioning new engineering practices that better reflect culture and diversity). Interestingly, the largest positive gains were in students' self-rated confidence to talk with friends about the concept of "intersectionality", and how to apply social science and humanities research on culture to their own fields of study in engineering. The smallest gains were observed in students' confidence in their ability to integrate diversity and culture into engineering processes, design, and research.

However, in questions used to gauge interest, response tended to either remain somewhat constant or decrease. It is possible that after completing a 10-week course on diversity and culture in engineering, students were fatigued with the topics. This decrease in interest is consistent with the small number (fewer than ten) of students who chose to pursue spring quarter course continuation options (which could also be attributed to other factors such a scheduling

Table 2. Relevant Statistics from Calibration and Recalibration Surveys

Survey Question	**Sample size**	**Calibration Score**		**Re-Calibration Score**		**Net change**	**Significance of paired sample t-test**
		Mean	SD	Mean	SD		
How would you rate your **current interest** in: Analyzing the characteristics of "engineering cultures"	12	3.58	0.79	4.00	0.60	0.42	NS
How would you rate your **current interest** in: Investigating how experiences in engineering cultures vary for different groups of people	12	4.33	0.65	4.17	0.58	-0.16	NS
How would you rate your **current interest** in: Developing deeper insights into how culture, diversity, and gender affect your own engineering or educational pathways	12	4.42	0.67	4.17	0.94	-0.25	NS
How would you rate your **current interest** in: Identifying new methods, techniques, or practices to use in engineering work that take culture, diversity, and gender into account	12	4.75	0.45	4.25	0.75	-0.50	NS
At this time, how **confident** are you in your ability to: Integrate considerations of diversity of people into design, engineering, and/or research questions	12	2.42	0.90	3.25	0.45	0.83	*
At this time, how **confident** are you in your ability to: Integrate considerations of culture into design, engineering, and/or research questions	12	2.50	0.80	3.08	0.67	0.58	NS
At this time, how **confident** are you in your ability to: Advocate for the consideration of diversity and culture in professional settings where decisions and policies are being made	12	2.50	1.00	3.67	0.89	1.17	**
At this time, how **confident** are you in your ability to: Seek out other people to whom to listen as a way to learn and be inspired to action	12	3.00	0.95	4.33	0.89	1.33	***
At this time, how **confident** are you in your ability to **describe**, in conversation with friends: How diversity of people relates to engineering work	12	2.67	1.07	4.00	0.60	1.33	***
At this time, how **confident** are you in your ability to **describe**, in conversation with friends: The concept of "intersectionality" in exploring people's identities and experiences	12	2.33	0.99	3.75	0.62	1.42	**
At this time, how **confident** are you in your ability to **describe**, in conversation with friends: How culture shapes which problems get solved in your field of study	11	2.73	0.79	3.73	0.91	1.00	*
At this time, how **confident** are you in your ability to **describe**, in conversation with friends: How to apply findings from social science and humanities research on culture to your field of study	12	2.00	0.85	3.58	0.90	1.58	***
At this time, how **confident** are you in your ability to **describe**, in conversation with friends: How culture is changed in groups, departments, and organizations	12	2.33	0.89	3.58	0.90	1.25	**

SD = Standard deviation, *** p<.001, ** p<.01, * p<.05, NS=Not significant

Note: Interest items measured on a 5 point scale, from 1=Not interested to 5=Extremely interested.
Confidence items measured on a 5 point scale, from 1=Not confident to 5=Extremely confident.

and course requirements). At the same time, while there may have been decreases in various aspects of interest, those decreases were small, and the average student still ranked their interest just above 4, corresponding to being "very interested". An increase from the already high initial scores would have been statistically improbable, so the slight decreases we observed were not unexpected or especially concerning.

In addition to the pre/post data, the mid quarter and final course evaluation processes administered through institutional channels gave students an opportunity to assess course learnings and outcomes. As noted earlier, a much larger number of students participated in these "official" forms and feedback mechanisms. The collected data, shown in Figure 1, show that students generally believed the class accomplished what it set out to do in terms of learning objectives. Other data corroborate that students felt they learned a great deal from EEL. From the open-ended portion of the student evaluations regarding advice students had for those considering taking the course, the sentiment was overwhelmingly positive. Most students advised that other students should take the course and stressed the amount of material they learned from taking the course. These responses included:

"[I learned how] to articulate and discuss issues surrounding diversity in engineering spaces."

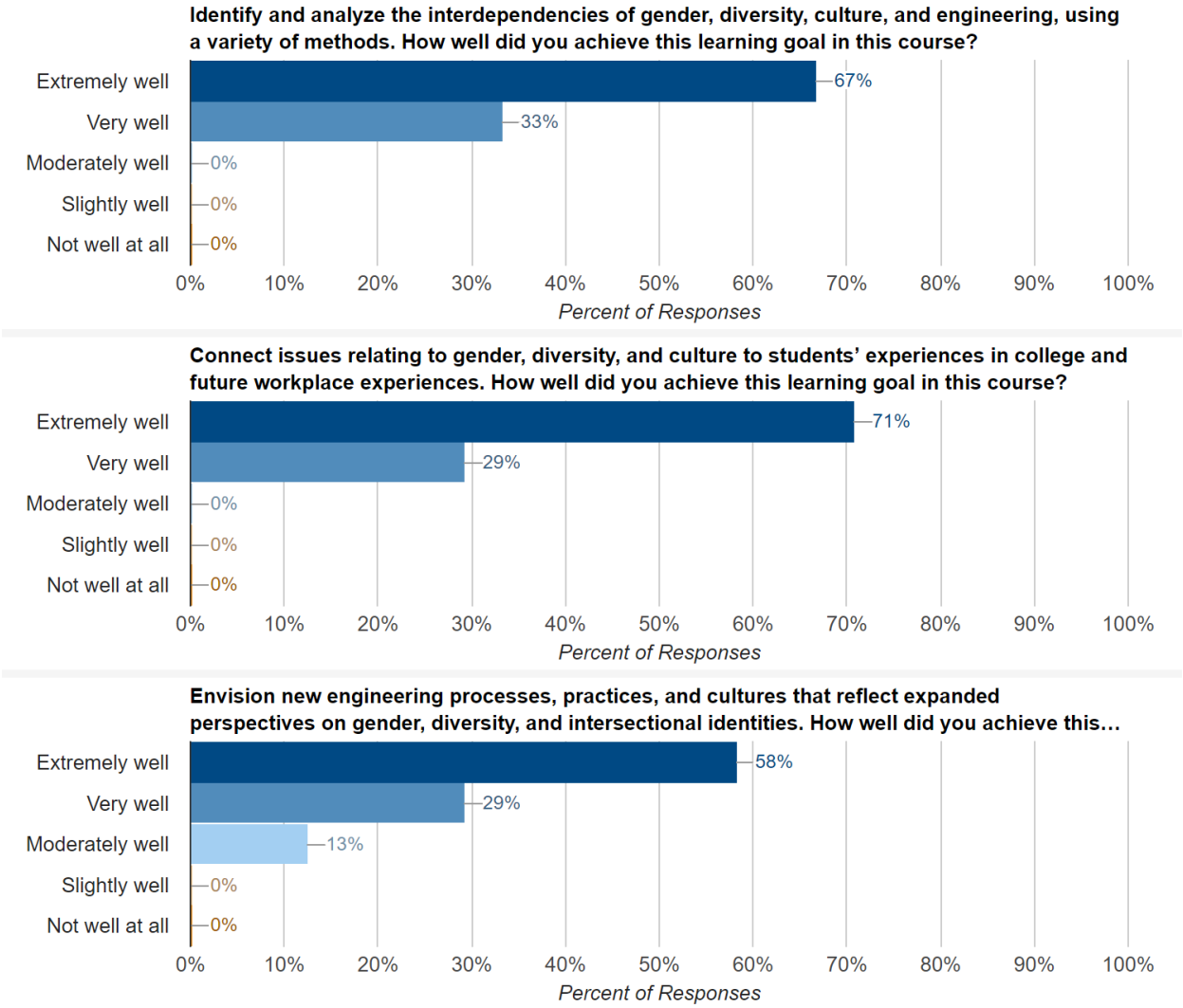
"I learned how to think more carefully about diversity and how I can take a stand to protect diversity of people … as well as how to think about change on a broader more institutional level."

"I feel that I am better able to form my arguments around ideas and statistics when it comes to talking about engineering diversity in college and career. I'm excited to learn more and use this as a base to launch into further topics..."

"This course is wonderful, I highly recommend it! The instructors and guest speakers are all enthusiastic, passionate, and knowledgeable. The community of students is fantastic, because we all are [interested] in the same topic- diversity- and bring our different perspectives to have conversations that are not only fascinating but also enlightening. I believe this class helped me learn how to be more considerate of others but also more bold and straightforward in asking for what others and myself deserve."

"[It's] definitely a course that every engineering student should take!"

Figure 1. Excerpted Final Course Evaluation Data



Data collected from Stanford course evaluations with prompt "how well did the course achieve the learning objectives…"
Note: Data represent a 72.7% response rate to this question by course participants

IV.2 Course Outcomes – Lived Experience

Lived Experience

This paper is designed to share not only the structure and "outcomes" of the course, but also lived, firsthand experience of the course through the eyes of the lead author (Onyeador), a student in EEL 2017. Throughout this paper, I (Onyeador) include my personal evaluation of the course, in order to draw out course impact and possibilities. My co-authors—instructors and designers of the course and advisors to my independent study—reviewed drafts of the paper and contributed to the writing of course design, but the lived experience shared here is my own. Much of this lived experience is based on notes taken as part of an independent study project on

my EEL course reflections during the quarter following my participation in EEL. Included in the notes were my reflections on the course content and experience as well as conversations I had with other students and the course teaching staff.

V. Recommendations for Practice

From student feedback, EEL appears to have had a positive impact; by taking the course, students were better equipped to tackle issues related to diversity in engineering spaces. We now extend this paper in important and unique ways by also including the lived experience of the lead author (and therefore now shift to the first person).

I came away from the course with new insights about both culture and diversity. More specifically, key ideas were developed around culture being the lens through which we see the world, affecting how we view the world and how we think and interact [22]. Culture establishes social norms and beliefs. The meaning of diversity varies with context. When the term diversity was used in the context of EEL, it was often referred to as traits that differ from the stereotypical perception of what an engineer should be. These characteristics often correspond to lower levels of societal privilege. Usually, that stereotypical image is a White (sometimes Asian), cis-gender, heterosexual man. Socio-economic status, gender, sex, sexual orientation, race, and ethnicity, to name a few, are all areas that can contribute to diversity. For this paper, I will use these definitions of terms to describe the experience of the course.

My lived experience and subsequent reflections have allowed me to identify a number of unique and effective practices upon which the course was based. In identifying these practices, I have also conferred with some of my classmates (and indicate that by shifting to "we" in my descriptions).

Encouragement of Discussion

Discussion was the basis of EEL. The class was structured such that it was not a traditional lecture-based course. In each class session, students were given several opportunities to discuss presented ideas, either in small groups or with the entire class. Even during those lectures that featured a substantial amount of lecturing, like those with guest speakers, students were always given an opportunity at the end of the class to ask questions of the speaker. Discussion is key to meaningful discourse, helps students engage with course topics, and gives students an opportunity to voice their thoughts [23]. In addition, I believe by assigning discussion circles, the course instructors facilitated interactions between students who had not necessarily met before, which provided those students the opportunity to hear new perspectives. During larger class discussions, after the smaller discussion groups had finished talking, instructors often randomly selected students to report out, encouraging participation from all students, providing a platform for even the more soft-spoken students. Literature supports that practices around discussion such as those used in EEL are beneficial for both comprehension and inclusivity [24], [25].

Small Class Size

I found that having a small class size was beneficial for inclusivity because it aided in class discussions. Because of the smaller class size, students had the opportunity to ask questions of other students, guest speakers, and the teaching staff. In larger classes, I do not believe there would necessarily be enough time to engage with the majority of students. The small class size also allowed students to share thoughts in discussion circles and share out with the entire class without taking an excessive amount of time. Additionally, in my conversations with my classmates, we felt class size enabled students to build familiarity with their classmates, which assisted with honest discussion and allowed more students to feel comfortable speaking, and it provided the intimacy required for meaningful discussion. While a smaller class size allows fewer students to enroll, it also lends itself to active engagement. In order to maximize inclusivity, despite this apparent contradiction, more class sessions could be held to allow more students the opportunity to take the course.

Engaging Readings, Guest Speakers, and Class Structure

The students offered positive feedback on the guest speakers and the readings they did outside of class. The general consensus was that even though students were required to complete the course readings and attend class sessions as part of their grades, students enjoyed the work. We felt the varied class structure prevented the class from falling into a monotonous pace from session to session. The structure also provided additional “intrigue” to the course and gave students more to look forward to. Guest speakers were an added benefit to the class because they provided perspectives students might not have otherwise gotten to hear. These perspectives included Professor Karan L. Watson, Provost and Executive Vice President at Texas A&M University, who spoke of her efforts to improve inclusivity at her university; Mary Anderson, the Director of Global Product Development HR at Ford Motor Company, who spoke of the diversity initiatives in industry; and many others.

Appropriate Courseload

I believe courseload was appropriate for the number of units and for the makeup of the class. The class comprised primarily engineering majors. As such, most of us students were not used to regular lengthy reading and writing assignments, and the course reflected this in the brevity of its assignments. Because the reading assignments were not excessively lengthy, we were more inclined to perform close reading rather than skimming. Instead of assigning work for work's sake, student learning was facilitated through discussion, which has been shown to be an effective learning technique [23].

Inclusion of Graduate and Undergraduate Students

Before the class began, EEL was marketed widely to both undergraduate and graduate (Masters and PhD) students, as a result, the class comprised almost equal numbers of undergraduate and graduate students. Students responded well to this mix. Throughout the quarter, students consistently expressed positive feelings about having both graduate and undergraduate classmates. I believe having both types of students present was beneficial because it provided a variety of perspectives. Most of the students had never been in a discussion-based class with both types of students, which made for unique interactions and learning experiences. Many grad students entered the class with an industry background which many of the undergraduates lacked. Many also came in having attended different undergraduate institutions from around the country, whereas undergraduates mostly spoke of their individual engineering experiences in the context of Stanford. Students responded well to the differences in perspective and those varied perspectives led to insightful discourse. From the standpoint of class inclusivity, opening the course to graduate and undergraduate students proved to be beneficial.

VI. Areas for Improvement

While the course was largely successful, there were several areas where the course could be improved. These were areas that did not achieve the same positive impact as those practices in the previous section. The areas for improvement were developed through the lead author's lived experience.

Focus on Gender

Although EEL was marketed as a course about diversity and culture in engineering, often times it seemed as though the focus of the course was on gender diversity, specifically on the role of women in engineering. It seemed to students that a majority of the readings in the class were dedicated to topics related specifically to women. Most of the speakers spoke primarily about the issues facing women in engineering and defaulted to anecdotal examples about women when discussing diversity. Since the class was not meant to specifically focus on gender diversity in engineering, I believe learning opportunities were lost to this bias towards women. There was a significant number of men in the class, some of whom expressed that they felt alienated by this bias at times. This approach also may have painted the false narrative that there is a singular female experience. The skewed focus on gender was likely due to the accessibility of information about women, as there is more readily available information about women than there is about any other minority group in engineering. That the class was also cross-listed as a FEM course likely also contributed to the skewed perspective. Furthermore, some students felt the language used in the course surrounding gender was at times unnecessarily binary, and often disregarded the gender spectrum. Binary language can be quite detrimental for inclusivity as suggested in recent papers [26]. Ideally, the class would equally address other types of diversity besides gender (i.e. race, sexual orientation, socio-economic status, etc.) in a more intersectional and critical way, which captures the nuances called for by Riley, Slaton, and Pawley [27].

Speaker Demographics

The majority of the speakers in the class were White and Asian women. While it was beneficial for the class to hear the firsthand accounts of women in engineering, the effect was that students felt the course was presented from a singular experience. More under-represented minority speakers of all genders would add to the variety of experiences presented in the class and give a more complete representation of experiences in engineering.

Facilitating Action

Some students left the course feeling frustrated. They felt they had learned a plethora of useful information but had not necessarily learned concrete ways to turn those ideas into action. Many students voiced the discouragement they felt as a result of becoming more aware of the issues within engineering and not knowing ways to resolve those issues because of their complexity. Some described the course as a wakeup call that left them with a bleak outlook on the future of diversity in engineering. EEL disheartened students by not providing more pragmatic ways for students to affect change.

Content of Assignments

EEL was designed such that it did not require much work to be done outside of class. The two major assignments for the course, the reflection papers, were limited to a few pages each. Because there was so much to cover in such short papers, it was difficult for students to be particularly in-depth in their analyses. As a result, most of the topics picked for reflection papers were broad, abstract, and somewhat idealistic. They included solutions like: employers should be careful about how they implement blind resume screenings and women in positions of power should create mentorship programs within industry. While these are valid ideas, they were not strategies that students could employ right away, which contributed to the students' feelings of inefficacy. The conversation projects also lacked a specific deliverable beyond any notes students may have chosen to take. While this lessened the workload, some students felt the projects were less impactful as a result. While the majority of the assigned readings did have a specific deliverable, the reading responses for example, many students had the expectation of engaging with the reading material in class. That expectation was not always met. The course had an immense amount of material to cover, so readings often went unaddressed during class time. I feel more deliberate assignment deliverables would have provided the “intentional engagement” necessary for critical thinking [25].

Creating True Safe Spaces

From my conversations with other students, I learned there were times when other students did not feel comfortable voicing their opinions in the course. Some felt the classroom environment was not as safe a space as they would have liked. Students with dominating personalities sometimes made it difficult for others to speak in discussion circles or in full class discussions.

Those with opinions in the minority were also more likely to face judgment for voicing those opinions. Because of the large percentage of students who were women or belonged to ethnic/racial minority groups[1], those who did not identify with those groups felt at times that they were not in a position to offer their perspectives because they might not be well received. In addition, in discussion circles that were less structured, the presence of dominating personalities led to one-sided conversations. All of this was a detriment to the course's inclusivity. From personal experience (Onyeador), students didn't always feel comfortable disagreeing with presenters. Sometimes speakers would voice their opinions as fact, and, because of the inherent power dynamic, students were not always comfortable voicing their thoughts to the contrary. The Center for Faculty Excellence and the University of North Carolina stresses the importance of providing spaces that are safe not just for discussion but also disagreement [25]. EEL attempted to provide a forum for free and open discussion, but I felt it fell short at times.

VII. Conclusion

EEL was a diversity education course at Stanford focused on exploring ideas relating to diversity and culture in engineering spaces. In this course, instructors embraced their roles as facilitators of learning, not just lecturers. They placed the focus on student discussion and interaction with ideas. By several measures, the course was met with positive student reviews. From the Calibration and Recalibration Surveys, we see preliminary evidence of the high levels of interest in the course and the increase in students' confidence around speaking about course topics. From the official course evaluation form, we see that students perceived the class to meet its learning objectives fairly well. While this case study only covered a single implementation of EEL, it highlights the potential for formal diversity education to make a positive impact on the way engineers view diversity in the field.

However, there were areas for improvement. The course focused on gender more so than other aspects of engineers' multi-dimensional and intersectional identities. Greater racial/ethnic and gender diversity was needed among guest speakers. Student discussion was vulnerable to the very markers of exclusion that the course content aimed to expose. These elements serve as a caveat to EEL's impact in its 2017 design and represent an opportunity for re-design in other iterations. Indeed, some of the effective practices and areas of improvement from this paper are already being used to improve EEL's 2018 offering. The class is now cross-listed not just in Engineering and Feminist Studies but also in Race and Ethnicity Studies. Additionally, the course is officially certified to fulfill an undergraduate general education requirement ("Engaging Diversity") as well as a Technology in Society requirement for undergraduate engineering students. As a result, it is now a course offered for 2 or 3 units, with students taking it for 3 units also completing a hands-on, action-oriented project; and beyond "diversity" and "culture", the

[1] The teaching team did not require students to self-report their gender or race, but many students described their identities within the course and both the gender and racial/ethnic diversity within the student community was evident.

course offers a stronger foundation for understanding and discussing “power” and “privilege”. Invited speakers reflect greater gender, racial, and ethnic diversity, and readings reflect perspectives from a variety of theoretical frameworks, as well as more research on experiences of those whose intersectional identities are less common in engineering. Future action items include more concerted strategies to sustain student interests in culture, diversity, and gender over the balance of their coursework, and to consider how to strengthen course learnings to students’ other engineering projects and assignments.

Although EEL was not perfect, it was still largely a success, which is especially noteworthy because the content of the course fell in a somewhat uncharted territory: diversity education. Given the small sample sizes from the data collected and the single course offering, we cannot make wide recommendations, but, from the course, we find several effective practices for engagement. One could envision the multitude of ways these practices could be adapted for use in other courses that aim to address similar issues and also in courses that do not. We can also look to EEL as a stepping block for achieving even further success by improving in the areas where the course fell short. Engineering faculty and industry professionals can take learnings from this course and expand them to courses like it and to other engineering courses that are not specifically focused on engineering or even use the learnings to develop strategies to promote diversity and inclusivity more widely in the field of engineering, perhaps by explicitly integrating and teaching diversity-related skills as a necessary competency for industry work.

Future research could expand upon this case study by collecting survey data from students who take future iterations of the course, with more dedicated effort to generate higher participation rates. Doing so would allow us to observe larger trends and draw more generalized conclusions. In order to improve inclusivity, more analysis is needed of Calibration Survey data on motivations of students. It would also be beneficial to collect data from students who chose *not* to take the course (perhaps those who sign up and then drop the course in the weeks leading up to, or immediately following, the start of the term). By longitudinally examining the experiences of students in this comparison group, stronger inferences about course impact could be made (not to mention strengthen understanding of how to increase students' interests in taking the course). A similar research direction could include collecting calibration and recalibration surveys, similar to that used in this case study, from students taking more traditional engineering classes to compare changes in comprehension and interest rates in those subjects before and after completing the courses. Still other research directions include alumni surveys to follow-up with students who participated in the course and meeting with industry employers to assess their perception of the marketability of the course. For the purpose of the current paper, we adopted a relatively informal approach to case study research, whereby a single course was conceived as yielding insight into the larger issue of diversity education within engineering, but just two methods were selected to investigate this “case”. Future research on courses such as EEL might benefit from more explicit “case study” framing and formalized methods (as articulated by Eisenhardt [28] and Creswell et al. [19], among others).

I (Onyeador) had several motivations for taking EEL in the winter of 2017. While I hoped to fulfill a requirement necessary for my engineering major, my primary motivation for taking the course was that, as black woman, I was familiar with the issue of the lack of diversity in engineering spaces and I wanted to engage with other students and faculty members who were also not just aware of those problems but were interested in developing solutions to those problems. During the course, I also had the opportunity interact with other students and the course instructors. From my experience and the course data, I consider the course to be successful as I was able to more deeply engage with topics of diversity and redefine how I think about engineering culture. As a result, I am able to think more critically about the social aspects of the engineering work that I do. I believe students who take courses like EEL will be able to incorporate and embrace more inclusive practices into our engineering careers and become better problem solvers than we would otherwise be.

References

[1] E. Suntanto, "Turning Diversity into Competitive Advantage: A Case Study of Managing Diversity in the United States of America," *Jurnal Manajemen Dan Kewirausahaan*, vol. 11, no. 2, September 2009. [Online] Available: http://fportfolio.petra.ac.id/user_files/91-022/MAN09110206.pdf [Accessed Jan. 30, 2018].

[2] S. Sheppard, K. Macatangay, A. Colby, and W. M. Sullivan, *Educating Engineers: Designing for the Future of the Field*. San Francisco, CA: Jossey-Bass, 2009.

[3] B. von Unold, "Fostering Innovations by Contextual Empathetic Design," M.S. thesis, Technical Univ. of Munich, 2017.

[4] A. Osagiede, M. F. Cox, B. Ahn, "Purdue University's Engineering Leadership Program: Addressing the Shortfall of Engineering Leadership Education," in *Engineering Leadership Development Division Technical Session Proc. 2013 ASEE Annual Conf. & Expo.*, Atlanta, GA, June 23-26, 2013, pp. 23.1011.1 - 23.1011.12.

[5] Y. Lambrinidou, W. Rhoads, S. Roy, E. Heaney, G. Ratajczak, and J. Ratajczak, "Ethnography in Engineering Ethics Education: A Pedagogy for Transformational Listening," presentented at Ann. Meeting American Society for Engineering Education, Indianapolis, IN, June 15-18, 2014.

[6] C. Corbett, and C. Hill, "Solving the Equation: The Variables for Women's Success in Engineering and Computing," The American Assoc. of University Women. 2015.

[7] W. Wulf, "Diversity in Engineering", *The Bridge*, vol. 28, no. 4, 1998.

[8] P. Hinds, D. Retelny, and C. Cramton, "In the Flow, Being Heard, and Having Opportunities: Sources of Power and Power Dynamics in Global Teams," in *Proc. 18th ACM Conf. on Computer Supported Cooperative Work & Social Computing*, Feb. 2015, pp. 864-875 [Online]. Available at: https://dl.acm.org/citation.cfm?id=2675199

[9] L. Jamieson, and J. Lohmann, "Innovation with Impact," American Society for Engineering Education, Washington, D.C., 2012 [Online]. Available at: https://www.asee.org/member-resources/reports/Innovation-with-Impact

[10] S. Shepperd et al, "ENGR311C/FEMGEN311C Winter 2017 Expanding Engineering Limits: Culture, Diversity, and Gender Syllabus," unpublished. December, 2016.

[11] "Faculty College: Expanding Engineering Limits: Culture, Diversity, and Gender," *Web.stanford.edu*, 2018. [Online]. Available: https://web.stanford.edu/group/design_education/cgi-bin/mediawiki/index.php/Faculty_College:_Expanding_Engineering_Limits:_Culture,_Diversity,_and_Gender. [Accessed: Feb. 2018].

[12] A. Levine, "Courses About Culture, Diversity and Gender in Engineering," 2016. [Online]. Available: stanford.box.com/s/kvnsblh0n126zqgyc1pgqggcvxlvu4cs

[13] T.A. Angelo and K. P. Cross, 1993. *Classroom Assessment Techniques*, 2nd ed. San Francisco: Jossey-Bass. p.148-53

[14] "Online Profiles", *Profiles.asee.org*. [Online]. Available: http://profiles.aseeorg/. [Accessed: Feb. 2017].

[15] E. A. Cech and T. J. Waidzunas, "Navigating the heteronormativity of engineering: the experiences of lesbian, gay, and bisexual students," *Engineering Studies*, vol. 3, no. 1, pp. 1–24, 2011.

[16] J. M. Smith and J. C. Lucena, "Invisible innovators: How low income, first-generation students use their funds of knowledge to belong in engineering," pp. 1-26, 2019. [Online] Available at: http://dx.doi.org/10.1080/19378629.2016.1155593

[17] S. Cheryan, V. Plaut, P. Davies and C. Steele, "Ambient belonging: How stereotypical cues impact gender participation in computer science.", *Journal of Personality and Social Psychology*, vol. 97, no. 6, pp. 1045-1060, 2009.

[18] N.A. Fouad, R. Singh, "Stemming the Tide: Why Women Leave Engineering", Milwaukee, WI: University of Wisconsin-Milwaukee, 2011.

[19] J. Creswell, W. Hanson, V. Clark Plano and A. Morales, "Qualitative Research Designs", *The Counseling Psychologist*, vol. 35, no. 2, pp. 236-264, 2007.

[20] "EXPANDING ENGINEERING LIMITS (2016-2017 Winter) Student Course Report", *What Do You Think?*, 2018. [Online]. Available: https://www.applyweb.com/eval/new/coursereport?sp=214143&sp=191118&sp=152216. [Accessed: Jan, 10 2018].

[21] A. Bandura, "Self-efficacy mechanism in human agency," *American Psychologist, vol. 37, no. 2*, February1982. [Online]. Available: https://www.uky.edu/~eushe2/Bandura/Bandura1982AP.pdf. [Accessed Jan. 30, 2018].

[22] H. R. Markus, and A. Conner, *Clash!: 8 Cultural Conflicts That Make Us Who We Are.* Avery, 2013.

[23] R. J. Marzano, "What will I do to help students effectively interact with new knowledge?" in *The Art and Science of Teaching.* Alexandra, VA: ASCD, 207, ch.2, pp. 29-57.

[24] K. Tanner, "Structure Matters: Twenty-One Teaching Strategies to Promote Student Engagement and Cultivate Classroom Equity", *Cell Biology Education*, vol. 12, no. 3, pp. 322-331, 2013.

[25] UNC Center for Faculty Excellence, "Teaching Controversial Issues", UNC Center for Faculty Excellence, Chapel Hill, NC, 2004.

[26] L. Hord, "Bucking the Linguistic Binary: Gender Neutral Language in English, Swedish, French, and German", *Western Papers in Linguistics / Cahiers linguistiques de Western*, vol. 3, no. 1, 2016.

[27] D. Riley, A. E. Slaton, and A. L. Pawley, "Social Justice and Inclusion," *Cambridge Handbook of Engineering Education Research*, pp. 335–356, Jan. 2015.

[28] Eisenhardt, K.M. (1989). Building theories from case study research. The Academy of Management Review, 14 (4), 532-550. Available at: http://www.jstor.org/stable/258557?seq=1#page_scan_tab_contents