Counteracting the social responsibility slump? Assessing changes in student knowledge and attitudes in mining, petroleum, and electrical engineering

Dr. Jessica Mary Smith, Colorado School of Mines

Jessica M. Smith is Associate Professor in the Engineering, Design & Society Division at the Colorado School of Mines and Director, Humanitarian Engineering Graduate Programs and Research. She is an anthropologist with two major research areas: 1) the sociocultural dynamics of extractive and energy industries, with a focus on corporate social responsibility, social justice, labor, and gender and 2) engineering education, with a focus on socioeconomic class and social responsibility. She is currently completing a book manuscript on the intersection of engineering and corporate social responsibility. She is the author of Mining Coal and Undermining Gender: Rhythms of Work and Family in the American West (Rutgers University Press, 2014), which was funded by the National Science Foundation and National Endowment for the Humanities. In 2016 the National Academy of Engineering recognized her Corporate Social Responsibility course as a national exemplar in teaching engineering ethics. Professor Smith holds a PhD in Anthropology and a certificate in Women's Studies from the University of Michigan and bachelor's degrees in International Studies, Anthropology and Latin American Studies from Macalester College.

Dr. Greg Rulifson P.E., Colorado School of Mines

Greg is currently a AAAS Fellow at USAID. Greg earned his bachelor's degree in Civil Engineering with a minor in Global Poverty and Practice from UC Berkeley where he acquired a passion for using engineering to facilitate developing communities' capacity for success. He earned his master's degree in Structural Engineering and Risk Analysis from Stanford University. His PhD work at CU Boulder focused on how student's connections of social responsibility and engineering change throughout college as well as how engineering service is valued in employment and supported in the workplace.

Courtney Paige Stanton
Dr. Carrie J. McClelland P.E., Colorado School of Mines

Carrie J McClelland is an Associate Teaching Professor at Colorado School of Mines. Carrie is a registered professional engineer with a passion for teaching the next generation of engineers to be well-rounded professionals who consider the technical aspects and the broader effects of their work. Her current research interests center on pedagogical interventions in the classroom, including how to best teach technical and professional skills.

Emily Sarver

Emily Sarver is an Associate Professor of mining engineering, and adjunct faculty to civil and environmental engineering, at Virginia Tech. Her teaching and research interests center on responsible resource production, occupational health, and mine environmental monitoring. Dr. Sarver teaches about sustainable development principles and practices for mineral and energy resource projects at the graduate and undergraduate levels.

Dr. Linda A. Battalora, Colorado School of Mines

Linda A. Battalora is a Teaching Professor in the Petroleum Engineering Department, a Payne Institute for Earth Resources Fellow, and a Shultz Humanitarian Engineering Fellow at the Colorado School of Mines (Mines). She holds BS and MS degrees in Petroleum Engineering from Mines, a JD from Loyola University New Orleans School of Law, and a PhD in Environmental Science and Engineering from Mines. Prior to joining the Faculty at Mines, Linda served in various roles in the oil and gas industry including operations engineer, production engineer, attorney, and international negotiator for oil and gas project development. She teaches Properties of Reservoir Fluids, Petroleum Seminar, Field Session, Fossil Energy, Environmental Law and Sustainability, and Corporate Social Responsibility. In addition to teaching in the

Petroleum Engineering program at Mines, Linda teaches courses in the Leadership in Social Responsibility, Humanitarian Engineering, Energy minor programs and the Natural Resources and Energy Policy graduate program at Mines. Linda is an active member of the Society of Petroleum Engineers (SPE) Health, Safety, Security, Environment and Social Responsibility (HSSE-SR) Advisory Committee and is Chair of the Sustainable Development Technical Section. She is also a member of multiple professional organizations including the American Society for Engineering Education, Association of International Petroleum Negotiators, American Inns of Court, American Bar Association, and the Colorado Bar Association. Her research areas include HSSE-SR, Sustainable Development, and the Circular Economy. She is a recipient of the 2018 SPE Distinguished Member Award, 2015 SPE Rocky Mountain North America Region Award for distinguished achievement by Petroleum Engineering Faculty award recipient, and the 2014 Rocky Mountain North America Region Award for distinguished contribution to Petroleum Engineering in Health, Safety, Security, Environment and Social Responsibility award recipient. She is also a SPE Distinguished Lecturer (2019-2020).

Dr. Stephanie Claussen, Colorado School of Mines

Stephanie Claussen is a Teaching Professor with a joint appointment in the Engineering, Design, and Society Division and the Electrical Engineering Department at the Colorado School of Mines. She obtained her B.S. in Electrical Engineering from the Massachusetts Institute of Technology in 2005 and her M.S. and Ph.D. from Stanford University in 2008 and 2012, respectively. Her current engineering education research interests include engineering students' understanding of ethics and social responsibility, sociotechnical education, and assessment of engineering pedagogies.

Dr. Susan K. Peterson, Marietta College
Dr. Nicole M. Smith, Colorado School of Mines

Dr. Smith is an Assistant Professor in the Mining Engineering Department at the Colorado School of Mines. She is a cultural anthropologist with research and teaching interests in livelihoods and extractive industries, corporate social responsibility, sustainable development, artisanal and small-scale mining, and engineering education.

Dr. Rennie B. Kaunda , Colorado School of Mines

Dr. Rennie Kaunda is an Assistant Professor in the Department of Mining Engineering at Colorado School of Mines, and a licensed Professional Engineer in the State of Colorado. Prior to joining academia, Dr. Kaunda spend 7 years in the mining industry where he worked on more than 50 global projects throughout Africa, Asia, South America and North America. Dr. Kaunda's areas of expertise are surface and underground rock mechanics, geotechnical engineering, numerical modeling and artificial neural network modeling. He has published/coauthored more than 13 peer-reviewed technical papers, 22 conference proceeding abstracts and 13 professional reports in addition to teaching classes and short courses on rock mechanics and geotechnical engineering. Dr Kaunda has performed or coordinated consulting services related to rock mechanics in surface and underground mines, and has also been involved in organizing and chairing sessions during several professional conference meetings.

Counteracting the social responsibility slump? Assessing changes in student knowledge and attitudes in mining, petroleum, and electrical engineering

Abstract

Social responsibility is a key touchstone of the engineering profession, yet research shows that engineering students' perceptions of the importance of public welfare actually decrease as they progress through the undergraduate curriculum. This has direct implications for the diversity of engineering students and workforces. Qualitative studies, for example, find that undergraduate women who place a high value on social responsibility leave engineering programs when they encounter unsupportive environments, decontextualized technical courses, and curricular difficulty.

This paper builds on prior literature by sharing the results of research that integrated critical social science perspectives on corporate social responsibility (CSR) into technical courses in petroleum engineering, mining engineering, and electrical engineering – three fields routinely characterized as enrolling the least diverse student bodies in terms of gender. Our data consist of three years of pre- and post-survey data for about 800 students in classes that included sociotechnical learning about CSR. Our previous research demonstrated that these course experiences broadened students' understanding of legitimate stakeholders and increased their interest in engineering ethics. In this paper, we explore whether this instruction influenced their desire to work for companies with positive reputations for social responsibility. Specifically, we investigate if students' ability to recognize CSR as an integrated sociotechnical endeavor that directly involves engineering (as opposed to CSR as a "social" activity such as volunteering that is separate from engineering) resulted in positive changes in their perceptions of business serving society and their own expressed desires to work for corporations with positive reputations for social responsibility. We find that while students' expressed desires to work for a socially responsible company increased from the beginning to the end of the course, those changes were not directly associated with viewing CSR as sociotechnical. Moreover, for the cohort data we have, those gains made from the beginning to end of a course did hold from year-to-year; rather, students expressed lower desires to work for socially responsible companies as seniors than they did as sophomores.

Introduction

Social responsibility is a key touchstone of the engineering profession, yet research shows that engineering students' perceptions of the importance of public welfare actually decrease as they progress through the undergraduate curriculum [1-2]. This has direct implications for the diversity of engineering students and workforces. Research with civil, environmental, and mechanical engineering students also finds that student perceptions of the connection between social responsibility and engineering shape their decisions to stay in their majors, and that women are more likely to leave engineering when they view those connections to be lacking and

encounter decontextualized technical courses and unsupportive environments [2-3]. Engineering educators frequently invoke research findings that women and racial/ethnic minorities are more sensitive to social justice concerns and more likely to pursue engineering careers with an explicit sense of social and environmental responsibility [1, 4, 5].

This paper builds on that literature by sharing the results of research that integrated social science perspectives on corporate social responsibility (CSR) into technical courses in petroleum engineering, mining engineering, and electrical engineering. In particular, we were curious if attention to CSR -- a controversial concept that aspires to align business interests with societal wellbeing -- would counteract the aforementioned social responsibility "slump" identified by engineering educators. We also sought to investigate if the influences of a critical yet constructive take on CSR on engineering students' views of social responsibility would vary by gender. For this analysis, we focus on our work in classes in petroleum engineering, mining engineering, and electrical engineering -- three fields that are routinely characterized as enrolling fewer numbers of women in comparison with other engineering disciplines. In the United States, women earned 21.9% of bachelor's degrees in engineering overall in 2018, but 16.9% of the bachelor's degrees in petroleum engineering, 16.3% in mining engineering, and 14.2% in electrical engineering [6].

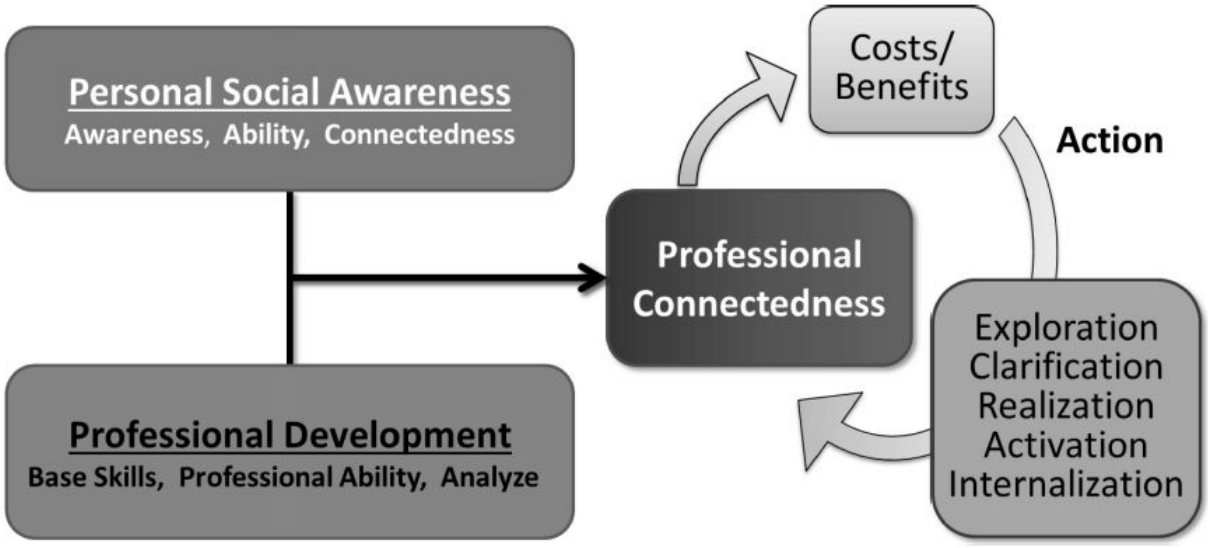
In this paper, we analyze students' self-reported desires to work for a company or firm with a positive reputation for social responsibility. Many engineers compartmentalize their personal and professional lives. One of the practicing engineers interviewed by Jessica Smith, for example, worried that his work directly enabled the expansion of oil, gas, and mining operations in wilderness areas. When asked how he managed that worry, he said, "You just put it out of your head. You just don't think about it; you compartmentalize. You join the Nature Conservancy and then you go out and look for gold." In remembering his corporate work, this engineer described a process of detachment from broader context and effects of his work – "you just put it out of your head" – that produced a compartmentalization of where and when he could invest himself in his work.

Engineering school is a prime opportunity for students to bring together their developing personal and professional social responsibilities. Canney and Bielefeldt show how this development happens in their Professional Social Responsibility Development Model (PSRDM) [7]. They operationalize this model in the Engineering Professional Responsibility Assessment (EPRA), which is a tool that has shown how social responsibility attitudes change over time and differ between gender, major, and volunteering experience.

Engineering students, like all students, come into college with influences from family, friends, and experiences. Until college, these have been almost entirely in what Canney and Bielefeldt

analyze as the personal realm of social responsibility development. Throughout college, in classes and internships, students learn about the professional realm of social responsibility: the engineering profession, its core values, and the priorities for people who are part of this profession. Without many experiences in classes or through co-curricular activities that show how personal and professional experiences can be integrated, students are likely to compartmentalize those senses of social responsibility. Those who do have significant opportunities to consider how their personal goals positively impact their work will go through an evaluative and reflective process, visualized below, to take stock of how they can live their personal social responsibility goals through their profession. Thus, Canney and Bielefeldt argue, the *professional connectedness* realm of social responsibility development requires engineers to consider the opportunity costs and benefits of their decisions. For example, working to benefit the marginalized or underserved from careers in NGOs or government agencies may result in less pay than careers in the corporate sector. A strong professionally connected social responsibility attitude can motivate towards action; personal willingness connects with professional abilities to recognize the power and opportunity s/he has to make a positive change.

Figure 1: Canney and Bielefeldt's Professional Social Responsibility Development Model [7, pg. 418]



In this research, our initial hypothesis was that positive changes in students' desires to work for companies or firms with good reputations for social responsibility would be at least partially explained by students coming to recognize CSR as a sociotechnical activity. CSR is an internally heterogeneous field of practice loosely aligned around the idea that businesses should pursue

profit in a way that generates social and environmental wellbeing or at least minimizes social and environmental harm [8]. Whereas "old" CSR centers around philanthropy and is critiqued for leaving harm-producing practices in place, "new" CSR aspires to align core business practices with the promotion of environmental and social wellbeing [9]. We included "new" CSR in our teaching for the project, as described below, because it would more directly involve transformations in engineering practice and decision-making.

Methods

A detailed explanation of our methods and the courses is available in our prior articles and papers [10-13], but we summarize the main components here.

1. Survey development and validation

The research team, in collaboration with other engineering educators and a panel of industry experts, developed, piloted, and revised a survey-based assessment instrument designed to be given to each student enrolled in each of the targeted courses, once at the beginning of the semester and once at the end. (Note: this was not the EPRA instrument developed by Canney and Bielefeldt.) Text of the complete survey is available in [12]. The survey includes 25 questions that are a mix of Likert-scale ranking questions and open-ended questions that gauge students' knowledge, attitudes, and skills relating to the intersection of engineering and corporate social responsibility.

After the first year of survey data was collected and analyzed, and talk alouds were conducted with students who had taken the survey, the team made changes to the assessment instrument to open up more and clearer spaces for students to criticize CSR. This paper reports only on classes that used the revised survey instrument.

2. Class instruction and survey deployment

As summarized in Table 1, this paper analyzes three years of course data (Summer 2016 - Fall 2019). Over that period, we included social science content about CSR in 25 separate classes in mining, petroleum, and electrical engineering at three different schools. Our study was purposefully designed to cover a variety of class types, including liberal arts electives, field sessions, core engineering science courses, and professional development courses, at a variety of points in students' undergraduate experiences (from first to senior years). A detailed analysis of what kind of CSR instruction happened in each class can be found in our prior publications [10-13]. We did not deploy identical modules or assignments because the content and needs of each class were different.

What did hold true across all of the classes was our focus on "new" CSR that directly implicates engineering decision-making and practice. For example, many of our assignments involved students proposing industrial projects or designs in ways that were responsive to stakeholder concerns and desires. We hoped that this angle would provide students with a meaningful lens from which to think critically about engineering and opportunities to harness it for social and environmental wellbeing, rather than considering social responsibility as something compartmentalized away from the practice of engineering itself. Therefore, our results should not be interpreted as assessing the influence of a particular style of CSR instruction. Our study here analyzes the influence of "new" CSR content being included in courses designed for engineering students.

3. Data analysis

For the purposes of this analysis, we considered only the students who gave informed consent to participate in the research and who took both the pre- and post-course surveys. We assigned each student a unique ID to match their pre- and post-course surveys. We then conducted paired t-tests and calculated the effect size to determine if the changes in student-by student responses observed over the course of the modules were statistically significant. We used the Microsoft Excel t-test function to determine the p values with a significance level of 0.05.

In this paper we analyze responses to two of the 25 questions on the survey instrument.

To assess professional connectedness, the primary question from the survey we analyze is the following: ***To what extent would a company's approach to corporate social responsibility impact your decision to work for them?*** We used a Likert scale: Very likely (2), somewhat likely (1), neutral (0), somewhat unlikely (-1), and unlikely (-2).

To investigate if there were relationships between students' stated desires to work for socially responsible companies and their understanding of CSR as a sociotechnical endeavor, we also analyzed responses to the following question: ***CSR is a diverse field of practice that varies by industry, location, and company. In this survey we use an umbrella definition for CSR: an approach to business in which companies collaborate with stakeholders to create shared economic, social and environmental value. How would you evaluate the following activities as potential examples of CSR?***

For this question, students then characterized the following examples as being an excellent example of CSR, an okay example of CSR, or not CSR, with the option of selecting "I don't know." The most "correct" answers that aligned with course content were scored with 2 points

and acceptable answers were scored with 1. Those values are reproduced here for our readers, but were not included on the survey.

- *A company providing training for members of a local community who want to open their own small businesses (2)*
- *A team of engineers redesigning an industrial process to minimize potential spills of hazardous materials after learning that residents are worried about pollution (2)*
- *A company giving college scholarships to children in the community where they operate (1)*
- *A company accurately and transparently reporting how much money it spends in another country (2)*
- *Employees doing charity or volunteer work in their free time (1)*
- *A company constructing a municipal wastewater treatment plant for a city that desires but does not have one, so that the company can reuse the treated wastewater in its own production process (2)*
- *An engineer reporting an unsafe practice to management or government authorities (1)*
- *A company prioritizing local residents when making hires for new jobs (2)*
- *An engineer changing the route of a pipeline to mitigate community conflict even though it will cost the company more money (2)*

Results and Discussion

In this paper, we analyze the responses of the 833 students who gave informed consent and took both the pre and post surveys in the classes under study. The classes varied in size, response rates, and students matched, from 78 matched responses out of 152 at the large end to 13 matched responses out of 17 at the small end. This variance raises caution in interpreting the results of statistical tests, though we were able to demonstrate significance with both large and small student pools. As we show below, perhaps even more significant than the size of the classes was the students' starting views of social responsibility; there were multiple classes that did not demonstrate a statistically significant increase in social responsibility attitudes because students began the course already with high scores.

Table 1 summarizes the student scores for each of the classes under consideration in this study. As described in the methods section, the significance and effect size tests were done on a student-by-student basis, testing changes in the same students' responses from the pre-course survey to the post-course survey. The starting average and ending average, however, obviously reflect changes in the classes as a whole.

Table 1: Summary of courses and student responses to the question: *"To what extent would a company's approach to corporate social responsibility impact your decision to work for them?*

		Class	Semester	p value, 1 tail*	Effect size	Start avg	End avg	Level	Students
Colorado School of Mines		PE Senior Seminar	Fall 16	0.423	0.179	0.75	0.79	senior	28
	Cohort 1	PE field session	Sum 16	0.007	0.000	1.11	1.41	rising junior	44
		PE reservoir fluid properties	Fall 16			0.73	0.97	junior	41
		PE Senior Sem	Fall 17	0.404	0.595	0.92	0.95	senior	78
	Cohort 2	PE field session	Sum 17	0.086	0.134	1.09	1.21	rising junior	67
		PE reservoir fluid properties	Fall 17			0.8	0.867	junior	13
		PE Senior Seminar	Fall 18	0.023	0.078	0.72	1.36	senior	11
	Cohort 3	PE Field Session	Sum 18	0.133	0.426	0.98	1.1	rising junior	61
		PE reservoir fluid properties	Fall 18	0.076	0.423	0.85	1.02	junior	55
		PE Senior Sem	Fall 19	0.382	0.131	0.81	0.85	senior	62
		PE Field Session	Sum 19	0.033	0.329	0.78	1.04	rising junior	54
		Introduction to Mining	Spring 17	0.215	0.276	0.94	1.06	sophomore	18
		Mining Geology	Fall 17			1.04	1.18	mostly juniors	26
		Semiconductor physics and device design	Fall 18	0.055	0.398	0.62	0.95	mostly seniors	21
		CSR	Spring 17	0.010	0.312	1.11	1.37	mostly senior	19
		CSR	Fall 18	0.336	1.028	1.08	1.15	mostly senior	13
		CSR	Spring 19	0.361	0.491	1	0.92	mostly senior	13
Marietta College		Engineering, Reasoning, and Ethics	Fall 16	0.014	0.764	0.24	0.95	first	21
		Engineering, Reasoning, and Ethics	Fall 18	0.045	0.545	0.66	1.11	first	27
		Engineering, Reasoning, and Ethics	Fall 19	0.029	0.617	0.81	1.2	first	21
Virginia Tech		Mine Reclamation and Environmental Management	Spring 17	0.368	0.649	1.28	1.33	senior	39
		Mine Reclamation and Environmental Management	Spring 18			0.7	1.19	senior	26
	Cohort	Introduction to Mining	Fall 16	0.344	0.423	1.33	1.38	sophomore	39
		Mine Reclamation and Environmental Management	Spring 19	0.401	1.626	1.22	1.26	senior	27
		Introduction to Mining	Fall 17	0.173	2.11	1.11	1.22	sophomore	9
		TOTAL STUDENTS							833

*$p<.05$

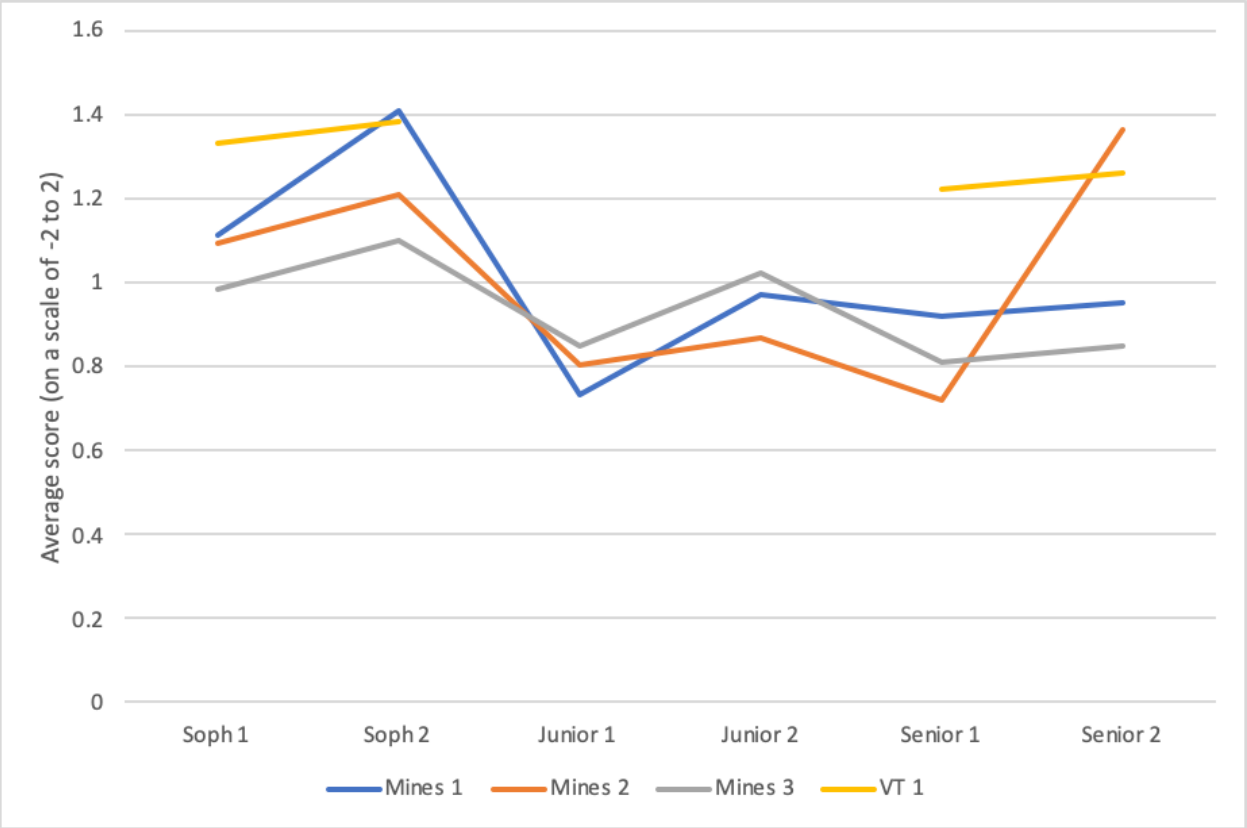
Note: Statistically significant changes are highlighted in green. The question was scored on a scale of -2 to 2. The cohorts are highlighted in colored borders, corresponding with Figure 2.

We were able to test four cohorts of students at multiple points of their undergraduate experience. In these cohorts, at least 80% of the students tracked from course-to-course. The cohorts are represented on Table 1 with bolded, colored boxes that correspond with Figure 2 below. For example, the Petroleum Engineering students at Mines went through a sequence from Field Session (taken in the summer between their sophomore and junior years) to Reservoir Fluid Properties (junior year) to Senior Seminar (senior year).

1. Social responsibility slump

First, we find mixed data about the social responsibility slump**.** We were able to survey four cohorts of students at multiple points in their undergraduate experience. Three of those cohorts showed students graduating from their senior year with lower scores in response to the question "*To what extent would a company's approach to corporate social responsibility impact your decision to work for them?"* than they did as rising juniors (1.11 to .95; .98 to .85; 1.33 to 1.26). In other words, students end a course reporting a greater desire to work for a socially responsible company, but they begin the following course expressing a lower desire than they expressed at the beginning of the previous course. Only one of the cohorts (Cohort 2 at the Colorado School of Mines) showed a marked improvement, from 1.09 (summer before their junior year) to 1.36 (senior year). Each of the senior seminars was taught by different instructors that used different course material, so it is difficult to pinpoint what made that cohort's senior-level instruction unique.

Figure 2: Class averages in response to the question: *"To what extent would a company's approach to corporate social responsibility impact your decision to work for them?*



Note: Each cohort is represented in a different colored line. Gaps in the lines represent years for which data was not collected (junior year in two of the cohorts). The cohort line colors correspond with Table 1.

We find it intriguing and concerning that the "improvements" -- students reporting a greater likelihood of desiring to work for a company with a good reputation for social responsibility -- we observe at the level of a class do not hold into the following class. One possible explanation is the social desirability bias in survey research, which shows that people answer sensitive questions with socially desirable rather than truthful answers [14]. In our case, this means that students may have reported greater desires to work for a socially responsible company because they received signals during the semester that their professor held that view, and were answering the survey questions in what they viewed as the "correct" way. We attempted to mitigate this bias by informing students in person and on the survey itself that their professor would not see their responses, but it is difficult to avoid this bias completely.

Aside from the social desirability bias, there are other possible reasons why students' attitudes may improve at the level of a class but lose ground as they advance through their undergraduate years. They may be experiencing the effects of what Cech terms the "culture of disengagement that defines public welfare concerns as tangential to what it means to practice" [1]. She

insightfully proposes that this culture of disengagement is rooted in the "ideology of depoliticization, which frames any 'non-technical' concerns such as public welfare as irrelevant to 'real' engineering work; the technical/social dualism, which devalues 'social' competencies such as those related to public welfare; and the meritocratic ideology, which frames existing social structures as fair and just." Elements of the culture of disengagement are present in each of the universities where we conducted the research. The social/technical dualism animates course flows at each of the universities and many students' perceptions of the value and difficulty of the "technical" courses inside of their majors and the "social" electives outside of them. Faculty perceive that students become immersed in their technical courses and can become a bit myopic when enamored of the new engineering concepts and industrial applications they are learning. Many of our students reacted strongly when they encountered CSR content in their "technical" courses, especially when those CSR concerns were raised as criticism of an industry they were seeking to join.

The "culture of disengagement" argument focuses on students' experiences inside of universities. For our own research, we cannot say that changes in student responses were solely due to their course experiences, since they all were taking other courses taught by other professors and absorbing information and perspectives from outside sources, such as news outlets, internships, and social networks. What we wish to emphasize here is that in addition to the messages that engineering students receive inside of universities and through the curriculum, *students are powerfully affected by the messages they receive from practicing engineers and employers during internships*.

Emily Sarver conducted pre-course surveys of the students in the sophomore and senior mining engineering courses at Virginia Tech between 2011 and 2013, prior to this research project. She found that romanticism evident among the sophomores about their ability to use engineering to promote sustainability and social responsibility had tempered by the time they were seniors. For example, one sophomore student wrote, "I like that mining engineering is involved quite a bit with the business end of operations… and things like ensuring good social license is just as important as the engineering itself." Another sophomore wrote, "I like the direction that the industry is moving by putting such a focus on sustainability. I'm excited to be part of a generation of engineers that are more conscious of the environment than ever before and I think we can make a difference in an industry that has had such a dirty connotation for so long." In contrast, a senior wrote that the concepts in the course (Mine Reclamation and Environmental Management) "aren't really applicable to what most mining engineers are going to be doing in the industry." Another senior wrote that most of their "impressions of what to expect have come from professors and people I've met through internships. For the most part these people have shown a dislike for the environmental and regulatory requirements placed on them because they slow down production." Working experiences may thus provide students an immediate sense of

the multiple constraints that exist on engineering practice and can exist in tension with social responsibility goals. This experience may prompt them to be more pragmatic or restrained in their social responsibility aspirations.

It may also be that seniors self-report lower desires to work for companies with positive reputations for social responsibility because they have already accepted job offers at companies with average or poor reputations in this regard and are calibrating their expectations to what they encountered on the job market. Moreover, the strength of the job market may make a difference in students' aspirations. In 2015, oil prices fell from near-record highs and production declined dramatically, reversing a boom in production and well-paying jobs that had originally attracted many students to study petroleum engineering. This market contraction meant that in 2015, 2016, and 2017, companies made few job offers and frequently rescinded those offers that they did make. The lower scores for the earlier cohorts of petroleum engineering students may signal that they were willing to accept a job at any company, with less regard for their reputation, because they perceived that they had few options open to them.

2. Students' desires to work for socially responsible companies and their views of CSR

Second, we find that the statistically significant improvements we observe in students' desire to work for socially responsible companies do not seem to be correlated with those students coming to view CSR as an integrated, sociotechnical phenomenon. This contrasts with our original hope and hypothesis. Seven of the classes (highlighted in green) showed statistically significant improvements. We cross-checked those classes with our prior research [13] that performed a statistical analysis of student changes in their response to the question that tested their view of CSR as a sociotechnical phenomenon. Of those seven courses demonstrating statistically significant changes in students' desires to work for a socially responsible company, only one (Marietta Fall 2016) also showed improvements in recognizing CSR as a sociotechnical practice. The other six showed that students were more likely to view CSR as the "old CSR" practices, such as volunteering, providing scholarships, and engaging in charity work, rather than the "new CSR" practices that made engineering itself more accountable to stakeholders. This surprising finding may suggest that even engineering undergraduates engage in compartmentalization when imagining their future careers, viewing social responsibility as something important to them yet separate from the practice of engineering itself.

We suspect that the ways in which practicing engineers and industry representatives represent CSR can also reinforce a social/technical dualism. During the first years we gave the survey, for example, some of the authors observed that some industry personnel spoke about CSR in a compartmentalized fashion, portraying CSR as philanthropy rather than central to engineering decision-making. Student chapters of the main professional association echoed this language and

emphasized philanthropy as the domain of social responsibility. It is possible that recent innovations in industry practice related to sustainability could present students with more sociotechnically integrated examples of CSR efforts, such as carbon capture, utilization, and storage; drilling automation; or drones used to detect methane leaks.

3. Impact of gender on students' desires to work for socially responsible companies

Third, we found preliminary evidence that women expressed a greater desire than men to work for a socially responsible company. Our analysis in this section focuses on a subset of the courses that demonstrated overall statistical significance in Table 1 and the large classes from Petroleum Engineering. This subset (n = 428) represents about half of the overall students.

Both men's and women's expressed desires to work for a socially responsible company increased over the course of the semester. In our survey sample as a whole, the average starting score for women was 1.078 out of a high of 2, and the average ending score was 1.333 out of a high of 2. In contrast, the average starting score for men was .798 out of a high of 2 and the average ending score for men was .988 out of a high of 2. In many of the classes, men's average *ending* score was similar to their women classmates' *starting* score. For example, the Summer 2016 Petroleum Engineering field session, the men's average ending score was 1.324, whereas the women's average starting score was 1.300. *Our research therefore provides some quantitative data that women students who persist in engineering do, on average, express higher desires to work for socially responsible companies than do their male counterparts.* This sample, of course, excludes women who leave engineering because they do not see connections between engineering and their senses of professional social responsibility [2-3]. This provides one possible explanation for why women engineering students seem to express greater desires for socially responsible careers: many of those who persist have been able to make the connection between social responsibility and engineering, whereas those who were not able to make the connection may have left.

We also separated out the men (n = 338) and women (n = 90) and conducted a paired t-test for the pre- and post-survey changes observed within each group. The observed changes from the pre- and post-surveys were statistically significant for both genders (men, p = .0003; women, p = .005). While we also conducted significance tests in each class for the changing starting and average scores for men and women, respectively, we caution against placing too much emphasis on them, given that the number of women enrolled in these courses was relatively small. For example, the Marietta 2016 ethics course enrolled two women out of a total of 20 students. One of the classes with the highest number of women was the Summer 2018 Petroleum Engineering field session, which enrolled 12 women out of 85 students.

Table 2: Gender analysis of student responses to the question *"To what extent would a company's approach to corporate social responsibility impact your decision to work for them?*

Class	Semester	1 tailed (T-test for significance (p<.05))		Effect size		Start avg		End avg	
		Male	Female	Male	Female	Male	Female	Male	Female
PE Senior Sem	Fall 16	0.340	0.302	0.213	-0.530	0.524	1.429	0.619	1.286
PE field session	Sum 16	0.036	0.018	0.279	-0.226	1.059	1.300	1.324	1.700
PE Senior Sem	Fall 17	0.333	0.413	-0.474	-1.108	0.932	0.895	0.983	0.842
PE Field Session	Sum 18	0.208	0.083	-0.374	-1.208	0.898	1.333	1.000	1.500
PE Senior Sem	Fall 19	0.454	0.217	0.079	0.258	0.787	0.867	0.766	1.133
PE Field Session	Sum 19	0.070	0.038	0.356	-0.603	0.739	1.000	1.000	1.333
CSR	Spring 17	0.041	0.086	-0.360	-1.083	0.833	1.571	1.083	1.857
Marietta ethics	Fall 16	0.028	0.250	0.665	1.500	0.263	0.000	0.895	1.500
Marietta ethics	Fall 18	0.059	0.211	0.561	-0.643	0.583	1.333	1.042	1.667
Marietta ethics	Fall 19	0.191	0.035	-2.438	0.458	0.875	0.600	1.063	1.800
OVERALL		**0.0003**	**0.005**	**0.112**	**-0.166**	**0.793**	**1.078**	**0.988**	**1.333**

Note: statistically significant changes are highlighted in green. The question was scored on a scale of -2 to 2.

4. Timing of critical CSR instruction

Fourth, we find mixed evidence for *when* critical instruction in CSR made the most meaningful difference in student perceptions. The only class that consistently showed statistically significant improvements in student perceptions was the course for first-year petroleum engineering students at Marietta, described in greater depth in our prior work [10] and below. These students also started off with the lowest scores of any of our students (.24, .66, and .81) but ended in the same range as the rest of the students (.95, 1.11, and 1.2). Two of the other courses that showed statistically significant improvements were in the Colorado School of Mines field sessions, which enrolled students in the summer between their sophomore and junior year. These data seem to point to the positive significance of early instruction in social responsibility themes, though these gains do not seem to hold throughout the rest of the students' time in college, as described above. There were two senior-level classes -- one seminar for petroleum engineering

students and one humanities and social science elective focused on CSR -- that did show statistically significant improvements.

5. Self-selection effects

Fifth, we find some evidence that specialized elective classes may be "preaching to the choir," as many educators may suspect. At the Colorado School of Mines, the students who enrolled in the CSR course generally did so to fulfil their required upper-division humanities and social science credit. The course was designed and taught to directly link CSR and engineering, and thus hopefully foster the kind of professional connectedness that is more difficult to encourage in classes that consider personal or professional responsibility separately. Students in the CSR course began the course with comparatively higher initial desires to work for socially responsible companies (1.0, 1.08, and 1.11). The other students at Mines who were taking required classes inside of their majors generally started with lower scores (as low as .72). This underscores the importance of humanities and social science professors collaborating with engineering professors inside of engineering courses rather than leaving their educational transformation projects at the margins [10-13]. This practice helps to disrupt the depoliticization and the technical/social dualism that frame social responsibility concerns as separate from engineering practice itself; even if engineering students are "required to practice public-welfare related reflexivity in social science or humanities courses, depoliticization and the technical/social dualism likely means that students bracket these concerns as external to their understanding of their professional duties" [1, pg. 50].

6. Effects of institutional culture

Finally, we find strong evidence of different student cultures, both by cohort and by school. The mining engineering students at Virginia Tech consistently self-reported higher desires to work for socially responsible companies than did the engineering students anywhere else, including the mining engineering students at the Colorado School of Mines. These students started both their sophomore and senior years with relatively high scores (1.22 and above) in core mining engineering courses. While it is difficult to say for certain why these students' scores are so much higher than their peers' scores on the same question, we do note that Virginia Tech actively promotes a culture of service among all of its engineering students and that, when recruiting new students, the mining engineering department also emphasizes service in the form of providing the materials necessary for everyday life.

The statistically significant changes consistently noted in the Marietta classes deserve special attention. While it could be partially due to the relatively lower scores with which students began, the course was different from the others in the study in substantive ways. It serves as a

First Year Seminar (FYS), and the 2019 syllabus describes the course to students as encouraging "self-discovery and an awareness of your strengths and interests. It provides opportunities for you to reflect on and make connections between your General Education classes, coursework in your major(s) and minor(s), and your lives beyond the classroom. The FYS challenges you to make meaning of the relationships between these experiences and to apply that knowledge in new situations and contexts." This course, therefore, is uniquely focused on helping students make explicit connections between the personal and professional responsibility domains theorized by Canney and Bielefeldt [7]. This may be particularly effective in cultivating professional connectedness, especially given that these activities are happening in an engineering course taught by engineers rather than in a humanities or social science course that can be perceived by students as separate from their core engineering work. It is likely also significant that Marietta was the only liberal arts school included in our study, which could have a variety of effects on student self-selection into the program and the broader messages they are receiving about social responsibility.

Finally, we also note significant differences by cohort, even within the same major in the same school. The Spring 2019 petroleum engineering graduates at Mines graduated with remarkably high desires to work for socially responsible companies (1.36 average), in comparison with the cohorts immediately preceding them (.79 and .95) and following them (.85). At Marietta, incoming petroleum engineering cohorts expressed consecutively higher desires to work for socially responsible companies (.24 to .66 to .81). This provides some evidence for faculty perceptions of cohorts having different overall attitudes, due to a complex mix of factors. In the mining and petroleum industries, this includes post-graduation employment rates, which are subject to boom-and-bust swings that significantly narrow and expand employment prospects.

Conclusions and future research

The data presented in this paper provide evidence about the influence of critical CSR training on engineering students' career aspirations, but it also poses new questions. We found significant differences in students' self-reported desires to work for companies with positive social responsibility reputations by course and school. We did find evidence for a social responsibility slump among some petroleum and mining engineering undergraduate students, which corroborates Cech's original findings [1] that focused on other majors. By focusing on cohorts of students in particular classes in a particular major, however, we also found preliminary evidence for at least one cohort of students who graduated expressing greater desires to work for socially responsible companies than when they began their major coursework. This paper tracked changes in student opinions at the level of a course. In our future work, we will track individual students course-by-course to see if and how their desires to work for socially responsible companies change over time.

On a positive note, we did find that students almost always end courses with significant CSR content expressing greater desires to work for socially responsible companies. This improvement, however, does not usually translate to their next course. This intriguing and perhaps discouraging finding raises important challenges for engineering educators. What can we do to help the gains made at the level of a course "stick" beyond the course itself? Our anecdotal data point to the significance of the messages students receive during their first job experiences for how students perceive the question of social responsibility.

We suspect that students' professional connectedness [7] could be enhanced by broadening students' views of the social responsibility of the engineering profession and their own agency inside of corporations. In this paper, we did not find that there was an easily identifiable correlation between students seeing CSR as sociotechnical in nature and desiring to work for socially responsible companies. We are eager to see if changes in the content of the curriculum -- for example, as the industry continues to innovate in response to growing challenges of climate change risk and resiliency -- affect students' understanding of CSR as a sociotechnical endeavor.

In future research, we are keen to see if there is a relationship between students' career aspirations and their views of the engineering profession itself. In future research, we will examine if positive changes in students' desires to work for socially responsible companies are related to positive changes in those students' views of: a) engineers' agency; b) the extent to which they believe CSR is efficacious in helping businesses serve society; and c) and the social responsibility obligations of their own careers. For (a), we will examine responses to the following survey questions:

1. *Who should play a role in deciding what companies will do as part of their CSR efforts? Check as many as appropriate. (Engineers are one possible answer among others.)*

2. *How should engineers play a role in a company's CSR activities?*
    - *Ensuring the safety of the artifacts, processes and products they design for the workers who use them*
    - *Ensuring the safety of the artifacts, processes and products they design for the communities impacted by them*
    - *Including community acceptance as a design constraint*
    - *Educating the public about the risks and rewards of a particular practice or product*
    - *Listening to communities to discover their concerns about a particular practice or product*
    - *Listening to communities to discover their knowledge about the environment*
    - *Listening to communities to learn how the business can serve their needs*
    - *I don't know*

For (b), we will examine responses to the following survey questions:

3. *To what extent do you believe that the practice of CSR helps businesses serve society? (Likert scale)*

4. *How important is each of the following for a for-profit company?*
   - *Health of local communities*
   - *Economic development of local communities*
   - *Safety of industrial processes*
   - *Security of a company, its employees, and capital*
   - *Environmental performance*
   - *Positive reputation among society at large*
   - *Positive reputation among stakeholders*
   - *Relationship with local government*
   - *Profit*

For (c), we will examine responses to the following survey questions:

5. *Which of the following CSR activities do you believe you will personally have to do in your own career?*
   - *Interact with people who live nearby facilities operated by your employer*
   - *Represent your employer in a public hearing*
   - *Respond to concerns at a neighborhood meeting*
   - *Interact with people who are opposed to your company or industry*
   - *Respond to media inquiries*
   - *Determine the most environmentally sound solution to a problem*
   - *Identify the relevant stakeholders for your company or project*

6. *How important are the ethical dimensions of engineering for your future career? (Likert-scale)*

We hope that by better understanding if and how students' desires to work for socially responsible companies relate to their perceptions of the engineering profession, including engineers' agency inside of corporations, we can help to chart strategies for enhancing students' professional connectedness.

References

1. Cech, E. (2014). Culture of Disengagement in Engineering Education? Science, Technology & Human Values, 39(1), 42–72. https://doi.org/10.1177/0162243913504305
2. Rulifson, G., & Bielefeldt, A. R. (2018). Evolution of Students' Varied Conceptualizations About Socially Responsible Engineering: A Four Year Longitudinal Study. *Science and Engineering Ethics*. https://doi.org/10.1007/s11948-018-0042-4
3. Rulifson, G., & Bielefeldt, A. (2017). Motivations to Leave Engineering: Through a Lens of Social Responsibility. *Engineering Studies*, *9*(3), 222–248. https://doi.org/10.1080/19378629.2017.1397159
4. Hunt, M. O. (2016). African American, Hispanic, and White Beliefs about Black/White Inequality, 1977-2004: *American Sociological Review*. https://doi.org/10.1177/000312240707200304
5. Litchfield, K., & Javernick-Will, A. (2015). "I Am an Engineer AND": A Mixed Methods Study of Socially Engaged Engineers. *Journal of Engineering Education*, *104*(4), 393–416. https://doi.org/10.1002/jee.20102
6. Roy, J. (2018). Engineering by the Numbers. American Society for Engineering Education. Available online: https://www.asee.org/papers-and-publications/publications/college-profiles
7. Canney, N., & Bielefeldt, A. (2015). A Framework for the Development of Social Responsibility in Engineers. *International Journal of Engineering Education*, *31*, 414–424.
8. Blowfield, M., & Frynas, J. G. (2005). Setting new agendas: Critical perspectives on Corporate Social Responsibility in the developing world. *International Affairs*, *81*(3), 499–513.
9. Auld, G., Bernstein, S., & Cashore, B. (2008). The New Corporate Social Responsibility. *Annual Review of Environment and Resources*, *33*, 413–435.
10. Smith, J. M., McClelland, C. J., & Smith, N. M. (2017). Engineering Students' Views of Corporate Social Responsibility: A Case Study From Petroleum Engineering. *Science and Engineering Ethics*, *23*(6), 1775–1790.
11. Smith N. M., Smith J. M., Battalora L. A., & Teschner B. A. (2018). Industry–University Partnerships: Engineering Education and Corporate Social Responsibility. *Journal of Professional Issues in Engineering Education and Practice*, *144*(3), 04018002. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000367
12. Smith, J. M., & Smith, N. M., & Rulifson, G., & McClelland, C. J., & Battalora, L. A., & Sarver, E. A., & Kaunda , R. B. (2018). Student Learning About Engineering and Corporate Social Responsibility: A Comparison Across Engineering and Liberal Arts Courses. Paper presented at 2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah. https://peer.asee.org/31007

13. Smith, J. M., & Rulifson, G., & Grady, C. L., & Smith, N. M., & Battalora, L. A., & Sarver, E., & McClelland, C. J., & Kaunda , R. B., & Holley, E. (2019). Critical Approaches to CSR as a Strategy to Broaden Engineering Students' Views of Stakeholders. Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. https://peer.asee.org/32567
14. Krumpal, I. (2013). Determinants of social desirability bias in sensitive surveys: A literature review. *Quality & Quantity*, *47*(4), 2025–2047. https://doi.org/10.1007/s11135-011-9640-9