A Natural Experiment: NAE's Changing the Conversation Report and Students' Changing Perceptions of Engineering

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Abstract

In 2008, the *Changing the Conversation* (CTC) report was published by the National Academy of Engineering to provide suggestions for how to talk about engineering to get students excited about the field. Since that time, some engineering schools have utilized the suggested messaging to greater extents than other schools. The Alfred P. Sloan funded Project to Assess Climate in Engineering (PACE) has 2008 and 2012 survey data from engineering undergraduates at 15 schools across the United States. The timing of the PACE survey enables examination of the extent to which the use of the engineering messaging has improved the perceptions of students at participating schools. The results from this qualitative analysis of quantitative and qualitative data suggest that schools that used the CTC messaging and principles generally saw a greater number of improvements in student perceptions of engineering than those that did not use the CTC messaging and principles. Further, using CTC principles in the curriculum appears to have a stronger relationship with student perceptions of engineering than using CTC to create recruitment and publicity materials.

Introduction

The National Academy of Engineering's *Changing the Conversation* (CTC) report provides recommendations for how to talk to students about engineering to engage them, interest them, and keep them in the field.[1] The messages portray engineering as a creative endeavor that can help others. Specific messages suggested by CTC include: Engineers are creative problem-solvers, Engineers make a world of difference, Engineering is essential to our health, happiness and safety, and Engineers help shape the future[1].

The Project to Assess Climate in Engineering (PACE) administered a climate survey in 21 engineering colleges in 2008 which garnered over 10,000 undergraduate student responses. PACE was re-funded by the Alfred P. Sloan Foundation to re-administer the survey in 2012. Administration occurred at 15 of the 21 original PACE schools in 2012 and over 10,000 students responded. One goal of the PACE study is to help schools understand how their climate has changed over the past four years, and how those changes might be related to the various interventions the school implemented.

The timing of the PACE surveys and the publication of the CTC report in 2008 results in an interesting natural experiment. This paper examines changes at the PACE schools from 2008 to 2012 specifically around survey items about perceptions of the engineering field, and perceptions of flexibility in engineering. These particular items were thought to reflect the ideas in the CTC messaging. The paper describes the activities at the schools that saw key improvements on the CTC related survey items, and those schools that did not see as many improvements. This research paper provides evidence of the influence of the CTC interventions at the PACE schools.

Background

There are various reasons why students may not be attracted to engineering. Students do not necessarily see engineering as a field where they can work with other people, contribute to society, or be creative[2,3]. In fact, many people don't really know what engineering is[2,3] and believe stereotypes and misconceptions, such as thinking that engineers are nerdy and boring[3], that engineering means working with machinery[2], and even confusing engineers with car mechanics[4]. Students want to choose careers that involve more creativity and challenge and that seem more socially relevant[3,5].

Currently, the economy is in need of more engineers than are available within the United States and Europe[2] which may be exacerbated by the fact that students are likely choosing majors outside of engineering based on misperceptions of the field. This is a troubling finding. Increasing the enrollments of women and minorities within engineering is particularly important[6,7]. One method of attempting to increase engineering enrollments has been to update messaging about what engineers do, to better reflect the reality of the engineering field and make it more attractive to students[2,3]. For example, Lopez-Martin[2] suggests using "clear information about the rewards of engineering professions" (p. 47) and Sinkele & Mupinga[3] identify "true knowledge of profession" (p. 37) and "realizing relevance to personal goals" (p. 37) as some of the main factors that should be included in programs to attract women into engineering. They further suggest a need to show how engineers "impact society, creatively solve real-world problems, and earn good salaries" (p. 38).

Some researchers and educators have implemented specific programs that provide messaging based on many of these ideas. For example, Lopez-Martin[2] updated a college of engineering website and marketing materials to include more relevant information such as profiles of working engineers and details about the challenges, rewards, and impact of working as an engineer. Another study, the Extraordinary Women Engineers Project, examined what types of communications would encourage women to pursue engineering. Findings suggest that women are more receptive to messaging that shows engineering is relevant, rewarding, and impactful and that includes personal stories and testimonials. They recommend that these qualities be privileged over traditional messaging that implies that engineering is difficult and only a good fit for students with very high levels of math and science proficiency[3].

Another attempt to provide evidence-based messaging for prospective engineering students was the 2008 National Academy of Engineering (NAE) report called "Changing the Conversation: Messages for Improving Public Understanding of Engineering." This report was based on qualitative and quantitative research on the engineering messages that young people find most compelling and interesting[1]. There has been increased interest in making sure that engineering and engineers are marketed in ways that attract a diverse range of students and students who might not realize what engineers can accomplish. A common problem is that K-12 students, and even K-12 teachers, often do not know what engineers do[8]. In addition, the report suggests that in the past, the public perceptions of engineering have been more closely tied to being good at math and science rather than what an engineering career looks like and what engineers can

accomplish[1]. The goal of the messaging campaign is to "encourage coordinated, consistent and effective communication" to a variety of audiences, by engineers[1].

The CTC report indicated that certain messages were more interesting to certain groups of people. For example, in the survey that was conducted, while both boys and girls found the message "Engineering makes a world of difference" most appealing, girls' second most appealing message was "Engineering is essential to our health, happiness, and safety" while boys' second most appealing message was "Engineers are creative problem solvers." The recommendations from the report suggest that targeting certain messages to certain groups (audience segmentation) may be the most effective means of branding engineering in a positive way. In fact, recommendation 2 says: "The choice of a specific message should be based on the demographics of the target audience (s)"[1 (p. 12).]

In the end, NAE suggested four main messages to be shared broadly. These are: 1) Engineers make a world of difference, 2) Engineers are creative problem-solvers, 3) Engineering is essential to our health, happiness and safety, and 4) Engineers help shape the future (Figure 1).

Figure 1. Four messages suggested by the NAE *Changing the Conversation* (CTC) Report.

The research also resulted in two suggested taglines: Because Dreams Need Doing and Turning Ideas into Reality. NAE also created a website at *engineeringmessages.org* that provides a tool kit with messaging examples and descriptions of what engineers should and should not be saying about their field. NAE has even begun utilizing a train-the-trainer approach to get the word out more broadly. The website also asks people to post how they have been using the messaging. Finally, *Engineers Changing the Conversation* is on Facebook.

Although the CTC report provides detailed recommendations for messaging which was developed through rigorous methodology, the study did not include the goal of assessing the effectiveness of these messages. The report suggests that one way to assess this would be with "a longitudinal study, combined with "dipstick" surveys before, during, and after the deployment of new messages"[1, (p.3)]. Although the PACE data used in this research is not truly longitudinal, in that a new sample of students was selected for the second survey, the CTC suggestion is in line with the methods and goals of the PACE study. Further, the authors were unable to find any additional studies examining the effectiveness of the CTC messaging for any outcome.

Method

Data

Data for this paper come from the 14 schools that participated in the Project to Assess Climate in Engineering online survey in 2008 and 2012 and provided data on CTC usage.

The PACE schools provided the research team with information about the degree to which they are familiar with and have implemented the messaging and principles from NAE's *Changing the Conversation* (CTC) report[1]. Of the 15 schools that completed both surveys, 14 schools provided the CTC usage data. Results are based on these 14 schools.

Measures

The CTC implementation variable was based on information received from the schools in four areas: whether engineering faculty and staff know and use CTC; whether departments outside of engineering, such as admissions, know and use CTC; whether CTC messaging has been implemented in recruiting and publicity documentation; and whether CTC principles have been used to inform course work and curricular choices. One point was assigned for each of these areas. This variable ranges from a value of zero to four. Schools with a CTC implementation score of zero were considered to have no CTC implementation, while schools with a score of two to four were considered to have higher CTC implementation. No school received a score of one.

To measure students' perceptions of engineering, the following ten survey items were used:

1. Engineers can leave and come back to their careers more easily than can people in other professions
2. Engineering is a field that supports people who want to have children and continue working
3. Engineers can design their own work schedules
4. Engineering is a field that supports a balance between work and family life
5. Engineers are well-paid
6. Society values the work engineers do
7. Engineering is an occupation that is respected by other people
8. Engineers help to make the world a better place
9. Engineering is boring
10. I expect that engineering will be a rewarding career

Items 1-4 measure student perceptions of the flexibility of engineering, while items 5-10 measure student general perceptions of the field of engineering.

Students responded to each item on a five-point Likert scale (strongly disagree; somewhat disagree; neutral; somewhat agree; strongly agree). Negatively worded items were reverse coded for analysis. The ten items above reflect various aspects of the CTC messaging. One of the goals of CTC is to support a different view of engineering and what it means to be an engineer. Items 1-4 portray engineering as a field with flexible options and good work/life balance. These survey items are indirectly related to the CTC messages. There has been increasing research

about the millennial generation who is increasingly interested in having a job that does not define them and doing work that blends with their lives outside of work[9]. Flexibility policies in the workplace are increasingly prevalent in order to meet the needs of these newer generations as well as Baby Boomers who now have eldercare issues requiring flexible workplaces. Therefore, improving perceptions about engineering as a flexible career opens up the field to newer generations of students for whom flexibility is required.

Survey items 5-10 more directly relate to the messaging. For example students who have internalized the CTC messages "Engineers make a world of difference" and "Engineers help shape the future" should be more likely to agree that Society values the work engineers do (Item 6) and Engineering is an occupation that is respected by other people (Item 7). Students who believe that "Engineering is essential to our health, happiness, and safety" would likely agree that Engineers help to make the world a better place (Item 8). Students who think that "Engineers are creative problem-solvers" will be unlikely to agree that Engineering is boring (Item 9) while students who agree with item 10 may have internalized any or all of the CTC messaging.

In addition, the millennial generation is likely to find the CTC messaging especially resonant since many want to help society in their work and life. In fact, "almost 70 percent [of millennials] say that giving back and being civically engaged are their highest priorities[9]." Thus, hearing that "engineers make a world of difference" is likely to interest more current students in engineering.

An aggregate school-level measure was created by PACE researchers to assess the extent of positive change from 2008 to 2012 in student perceptions of engineering. The number of items on which schools improved was summed into an overall improvement score for student perceptions. Improvement was assessed with a t-test ($p < 0.05$ significance level for all tests; tests used descriptively and therefore alpha level was left unadjusted) for each school and for each item comparing the 2008 mean value to the 2012 mean value. This measure was computed for all students within each school; for all females within each school; and for all underrepresented minority (URM) students within each school. Values for number of items with improvement varied from 0 to 9 since no school had improved on all ten items among any group. Schools with improvement on four or more items within any group were considered to have high improvement, while schools with improvement on less than four items within all groups were considered to have little improvement in student perceptions. Schools have been made anonymous by assigning them a letter of the alphabet. Histograms of these scores can be seen in Figure 2.

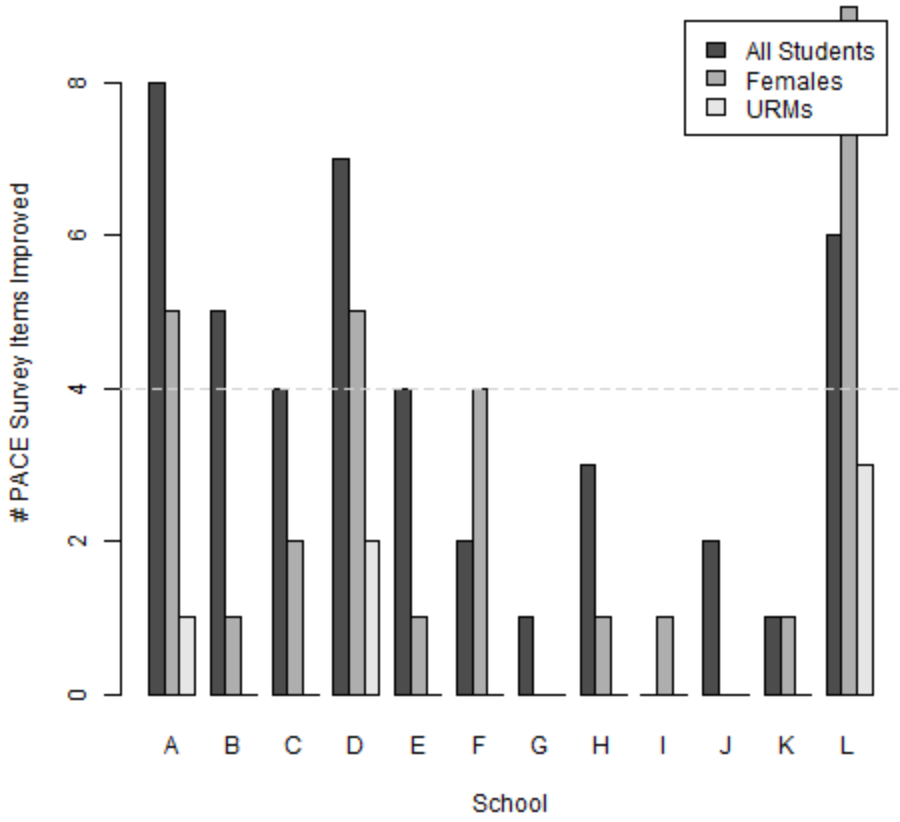

Figure 2. Number of PACE survey items on student perceptions of engineering with improvement for each school, for all students, females, and URMs, out of 10 items. Dotted line at 4 items represents the cutoff used to decide whether student perceptions improved at that school or not.

Students responded to demographic questions on the survey including gender and race/ethnicity. Students who identified as White, Asian, or Asian Indian were classified as non-underrepresented minorities (non-URM), while students who identified as African American, Hispanic, Native American, or Hawaiian/Pacific Islander were classified as underrepresented minorities (URM).

Data Analysis

Due to the small sample of schools available for this particular project (N=14), statistical analysis of these school-level scores lacked sufficient power for meaningful conclusions. Instead, the analysis provided here is primarily descriptive. Schools were quantitatively put into groups based on their level of CTC implementation and their improvements in student perceptions (See Table 1), but the types of CTC activities they reported were qualitatively analyzed to understand why the apparent relationships might exist.

This relationship is particularly interesting due to the timing of the CTC report. Because the report was released in 2008, the PACE survey data collected in spring of 2008 could not have been significantly impacted by CTC messaging, as the timing would not have allowed CTC principles and messaging to have been comprehensively implemented. This situation results in a natural experiment. By comparing the 2008 and 2012 data and relating it to the level of CTC implementation within a school, it is possible to assess whether there are any relationships between CTC implementation and improved student perceptions of engineering.

Based on measures of CTC implementation and improvements in student perceptions, the schools were assigned to either group 1 (schools with a high degree of CTC implementation, defined as a score of 2-4, and who saw high levels of improvement, defined as improvement on 4 or more items); group 2 (schools with no CTC implementation, defined as a score of zero, and who saw little improvement, defined as improvement on 3 or fewer items); and group 3 (schools whose improvement was not what would be expected based on our knowledge of their CTC implementation). Based on these descriptions, group 1 will be referred to as High Action, High Results, group 2 will be referred to as Low Action, Low Results and group 3 will be referred to as Unexpected Relationships.

Table 1. Categorization of PACE schools with respect to CTC implementation and improved student perceptions of engineering

		Number of Items with Improvement			
School	Level of CTC Implementation	All Students	Female Students	URM Students	Group
School A	2	8	5	1	1
School B	4	5	1	0	1
School C	3	4	2	0	1
School D	2	7	5	2	1
School E	2	4	1	0	1
School F	3	2	4	0	1
School G	0	1	0	0	2
School H	0	3	1	0	2
School I	0	0	1	0	2
School J	0	1	0	0	2
School K	3	2	0	0	3
School L	3	1	1	0	3
School M	3	0	1	0	3
School N	0	6	9	3	3

Note: Group 1 is High Action, High Results; Group 2 is Low Action, Low Results, and Group 3 is Unexpected Relationships. Number of items with improvement shows number of student perceptions of engineering survey items where schools improved from 2008 to 2012 out of a total of ten possible items.

Results

Six schools are included in the High Action, High Results group, four schools in the Low Action, Low Results group, and four schools in the Unexpected Relationships group The High Action, High Results group includes schools A-F, the Low Action, Low Results group includes schools G-J, and the Unexpected Relationships group includes schools K-N. Each group will be examined separately. In addition, each school provided the research team with different levels of detail about their implementation of CTC, so descriptions vary with respect to details.

High Action, High Results Group

Each of the six schools in this group reported a relatively high level of adoption of the CTC messaging and survey results indicated that student perceptions of engineering had improved from 2008 to 2012 in many ways within these schools. Most schools in this group showed more improvements among all students than among female or URM students specifically. The exception to this was School F where females showed improvement on four items, while all students showed improvement on only two items. All schools showed at least some improvement among females, with the number of items showing improvement ranging from one to five. For URM students the results were not as encouraging with only two schools showing improvements on any items for URM students and these schools only showing improvement on one or two of the items.

School A has incorporated the messaging in recruitment and retention activities. This school indicated that all of their recruitment staff actively used this messaging, and they also use the messaging in their recruitment postcards. This school indicated that they have not utilized the messaging in courses or curriculum, although it is hard to know to what extent individual professors use it in their own courses. They feel the messaging has been "fairly well adopted." Improvements were seen on items 1-5 and 8-10 for all students; items 1, 2, 4, 5, and 10 for female students; and item 8 for URM students. This represents improvement on 8 of the 10 items for all students, meaning that students at School A are increasingly seeing engineering as flexible and rewarding. In addition, School A saw many improvements for females including 3 of the 4 items dealing with flexibility of engineering and 2 of the 6 items dealing with engineering perceptions. Overall, it seems there have been important increases in the perceptions of engineering as family-friendly and flexible at School A.

School B reports that the deans, department chairs, and program managers have been made aware of the messaging. It is used in articles and publications including prospective student materials and promotional materials. In addition, CTC messaging is integrated into orientation activities, first-year seminar courses, and a spring open house. The college of engineering website highlights some of the activities and competitions that students can join in a way that is consistent with the messaging focused on making a difference to society. This school feels the CTC messaging has been adopted to a high extent. Improvements were seen on survey items 2, 6, and 8-10 for all students; item 10 for female students; and no items for URM students. Items 6, 8, and 10 all deal with the value of engineering and an engineering career and agreement with these items is consistent with the messaging in the materials and activities provided by the college of engineering.

School C has framed much of the freshman course progression on CTC principles, ensuring that first-year students are exposed to engineering from a perspective shaped by CTC once they enter School C. The dean of engineering at School C also frames much of his messaging with CTC, thereby setting the tone for the college as a whole. Undergraduate chairs, advisors, and faculty are familiar with CTC messaging. In addition, the CTC principles are used extensively in all college recruitment materials, including the women in engineering program materials. Improvements were seen on items 2-4 and 10 for all students; items 8 and 10 for female students; and no items for URM students. Considering the extent of the messaging in course and publicity materials, it makes sense that students increasingly agree with item 10, that engineering will be a rewarding career. For all students, improvement was seen on 3 of the 4 flexibility of engineering items.

School D has implemented programs outside of the classroom that make use of the messaging, such as an annual t-shirt contest. In addition, School D used CTC in a recent overhaul of their website, in recruiting materials, and in departmental brochures. New communication staff members are required to familiarize themselves with CTC messaging before communicating with the public about engineering. School D had improvements on items 4-10 for all students; items 5-8 and 10 for female students; and items 3 and 5 for URM students. School D saw improvements on many items, particularly ones involving perception and value of engineering. Whereas many schools saw few, if any, improvements for URM students, School D saw improvements on items for URM students including Engineers can design their own work schedules and Engineers are well-paid. Although it is not clear from the particular interventions exactly why School D has made these particular improvements with URMs, this school generally has a more diverse student body and may do more segmentation of their messages than other schools do.

Staff members in the engineering diversity center at School E are familiar with the CTC messaging. School E reported using the CTC principles in courses and curriculum, but not in recruitment or publicity materials. This is a bit different than what other schools reported where the messaging is most easily and readily implemented into recruitment materials. Although School E has used CTC, they feel that their overall adoption of the principles is relatively minor. School E saw improvements on items 1, 4, 9, and 10 for all students; item 2 for female students; and no items for URM students. Two of the items with improvements for all students relate to flexibility of engineering and two relate to general perceptions.

School F has implemented various programs and recruitment materials based on CTC messaging, but this work has been largely done by the Women in Engineering (WiE) program. For example, WiE has incorporated the messaging in their outreach and recruitment materials, and the director of WiE teaches a course that exposes students to different engineering careers and majors. School F did not have large improvements in student perceptions overall, but did see admirable gains in the perceptions of their female students, with improvement in four out of the ten items. Whether intentional or not, some of the work done by WiE may have been more effective for influencing women's perceptions than men's. Improvements were seen on items 6 and 7 for all students; items 2, 6, 8, and 9 for female students; and no items for URM students. With the exception of item 2, these improvements all relate to general perceptions of

engineering. Item 2 (Engineering is a field that supports people who want to have children and continue working) is an item that intuitively might have more relevance for females and it is the only item related to flexibility in engineering with improvements for females. The remaining three items relate to general perceptions of engineering. School F saw women's perceptions improve on the following general perception items: Society values the work engineers do, Engineers help to make the world a better place, and I expect that engineering will be a rewarding career.

Although each of these six schools implemented the messages from CTC differently, each has seen various improvements in student perceptions of engineering. Most of these schools (4 of 6) have incorporated CTC in course sequences (usually first year courses), the teaching of specific courses, or some other type of curricular material. Most of these schools have also incorporated the messaging into recruitment and outreach materials. All schools reported that at least some of the faculty or staff is familiar with CTC, and most reported that it is widely known within and outside their departments. Although some of these schools have seen more improvements than others, all have shown improvements on many items for all students and for females, while only a few have shown improvements for URM students.

Low Action, Low Results Group

The four schools in this group reported that they have not implemented the CTC messaging. These schools also had relatively low levels of improvement in their students' perceptions of engineering between 2008 and 2012. Among these schools, improvement for all students occurred on three or fewer items. For females, very little improvement was reported with two schools seeing no items with improvement and two schools each seeing just one item with improvement. No school in this group had improvements on any of the items for URM students.

School G reported that only the dean of engineering is aware of the messaging, others within the school are unaware of the messaging, and that it is not used for any recruitment materials, curricular programs, or anywhere else. School G had improvement on item 4 for all students and on no items for females or URMs. This item reflects improvements in one of the work/family flexibility items.

School H reported that minority program staff and deans are aware of the messaging, but that none use it for any purposes. School H had improvements on items 1, 3, and 5 for all students, on item 3 for female students, and on no items for URM students. Items 1 and 3 relate to perceptions about the flexibility of engineering and item 5 suggests improvement in the perception that engineers are well paid.

Similarly, School I has found no evidence that faculty or staff are familiar with the messaging or that it is used in any way. School I had improvement on item 7 for female students and on no items for all students or URM students.

Stakeholders at School J were generally unaware of this messaging, although they found that a few individuals and programs were becoming increasingly aware of it. They feel that although this has not been used in the past, it provides an excellent framework that they would like to

utilize in the future. School J had improvement exclusively on item 5, which relates to the perception that engineers are well paid.

Schools G, H, I, and J had improvements on only one, three, zero, and one item respectively. Each school in this group reported little to no implementation of the CTC messaging and principles and saw little to no improvement in student perception of engineering.

Unexpected Relationships Group

The four schools in this group do not follow the patterns in Groups 1 or 2. These are very interesting cases because they do not support the proposition of this paper. The section below attempts to understand what may be happening at these schools, but it is possible that we may be lacking the information needed to truly understand what is happening at these schools. Three of the four schools reported that they have implemented the CTC messaging in multiple ways, but there were relatively few improvements in student perceptions. In fact, of the ten perception items, these three schools saw improvements on only zero, one, or two items for all students, zero or one item for female students, and no items for URM students. One of the three schools (School N) reported that they had not implemented CTC messaging, but their survey results showed a large number of improvements in student perceptions. In fact, School N had the most number of items showing improvement for female students and for URM students of any school examined.

School K reported that many faculty and staff are familiar with CTC, including the college of engineering outreach coordinator, the dean, and chairs. The CTC messaging is included in marketing, communications, and admissions materials provided by departments and staff outside of engineering. In addition, School K has used the messaging to frame letters and promotional materials by including more females in publicity images and more stories about research experiences. This school has not used CTC for courses or curriculum. They feel they have implemented CTC somewhat but that the implementation is particularly within promotions and recruiting rather than at the departmental and curricular level. School K had improvements on items 1 and 2 for all students and no items for female or URM students. It is possible that this school has not seen particularly large improvements because the messaging has been used primarily in recruitment and is not as integrated in the current student experience. It is also possible that the application of the CTC messaging has not followed the suggestions from NAE as much as one would hope. For example, while including more images of women and describing research experiences should be helpful in recruiting a more diverse student body, it does not directly relate to the four primary CTC messages suggested by NAE. Regardless, although this school has generally not had the improvements one would expect given their level of CTC implementation, it is also clear that the level of implementation is more modest compared with other schools, and may be related to the relatively modest improvements. It is also interesting to note that School K seems to have implemented the CTC messaging similarly to School A, but with fairly different results. It is hard to say exactly what the difference might be, given the evidence provided, but it is worth further investigation.

School L reported that CTC messaging is used in outreach, recruitment, and retention marketing materials. Faculty and staff within engineering, as well as outside in departments such as media

relations and admissions, are familiar with the messaging. School L reports that they have not implemented the messaging in course sequence or curricular choices. School L feels that they have done a good job with educational outreach, but working with faculty to revise the curricula based on these principles might be a logical next step. School L had improvements on item 10 for all students, item 6 for female students, and no items for URM students. Similar to School K, the authors wonder whether the implementation of the messaging has truly been in line with recommendations. It is also possible that the lack of improvement relates to not having updated curricula based on CTC. In addition, the impacts of messaging used for outreach and recruitment may be better measured by examining increased enrollments by demographic group, rather than measuring changes in current student perceptions.

At School M, the staff within student affairs and the women in engineering program is aware of the CTC messaging. For example, outreach and recruitment events are focused on how engineers serve society and include real-world engineering examples. Talks and activities used in a summer program for high school girls make use of the CTC concepts. Additionally, more relatable examples have been integrated into class work, including a second-year requirement that students create a presentation explaining what engineering is to high school students. However, these programs were generally implemented before CTC and so are not directly based on the CTC report. Overall, School M feels that the CTC messaging has been adopted within pockets at their school. Generally, it helps shape their interactions with current and prospective students, but they have always tried to be positive in their interactions with students, even before making use of CTC. School M only saw one improvement which was for females on item 10, indicating females increasingly expect engineering to be a rewarding career. Although it seems that School M has implemented recruiting materials and programs and curricular changes in line with the CTC framework, it also appears that most of this work was done prior to the first survey administration, which may explain why almost no improvement occurred between the first and second survey. Additionally, the curricular changes implemented by School M are somewhat limited and focused more on recruitment than changes affecting the everyday experiences of most students. Although there has been a push to include more relevant examples and connections within coursework, School M does not believe that the professors who are teaching the engineering courses really think about the CTC messaging and the implication of some of these changes. Although it appears that School M has done a good job overall of integrating some of the CTC messages in specific ways, it appears that much of this work was done prior to the CTC report and that the curricular changes based on CTC and in the spirit of CTC may be limited in scope.

School N does not consciously implement CTC within their Women in Science and Engineering (WISE) program. However, they had previously developed messaging and examples that align with the CTC messaging prior to the release of the CTC guidelines. For all students, there were six items showing improvement; for female students there were nine items showing improvement, and for URM students there were three items showing improvement. These improvements were seen on items 1, 3, 5, 6, 8, and 10 for all students; items 1-8 and 10 for female students; and items 5, 8, and 10 for URM students. There are many improvements in perceptions of flexibility in engineering and general perceptions of engineering. It is interesting that the improvements for females were seen almost across the board, and it would be worth further investigating what messages or activities have been implemented at this school, even if

they were not developed directly in accordance with CTC principles. It seems plausible that the improvements this school experienced were related to the work they did developing and implementing improvements in messaging, even if they were only coincidentally in line with the CTC messaging.

Discussion

Broadly speaking, the schools that have implemented CTC messaging to a greater extent have seen greater improvements in student perceptions of engineering. It was expected that schools with a strong CTC implementation would show improvements in student perceptions of engineering, while schools with little to no implementation of CTC would show little to no improvement in student perceptions of engineering. Of the 14 schools examined, the majority of them (ten schools) followed these expected patterns (High Action, High Results group or Low Action, Low Results group) while four remained anomalous (Unexpected Relationships group). Although the data do not allow us to conclude definitively that implementing CTC causes perceptions of engineering students to improve, or even to conclude that the two are definitely related, it is clear that the trends we have observed generally support these propositions. The main objection to these propositions is the four anomalous schools.

Among these anomalous schools, it appears that Schools K, L, and M may have been more modest in their CTC implementation, while School N may be implementing messaging and choices in the spirit of CTC even if they are not directly due to CTC. In addition, it may be noted that two of the three schools that did not improve as much as expected did not implement any type of curricular change based on CTC, while four of the six High Action, High Results schools did implement curricular changes based on CTC. This result indicates that implementing curricular changes based on CTC may have a larger relationship with improved student perceptions of engineering than creating recruitment materials based on CTC. Given that recruitment messaging will likely be heard by the students only briefly during their college careers, it makes sense that the impact of these types of changes could be smaller for current students. Although there is still a lot of variability in terms of the types of things that more successful versus less successful schools implemented, the trend toward implementing curricular changes based on CTC looks promising for further investigation.

Limitations

There was one school for which information about the use of CTC was not available, and therefore this school was not included in this paper. This school had no improvements on the CTC-related items on the PACE climate survey. It is not known if there is a response bias operating such that this school did not respond to our requests because they have not been active in using the CTC messaging.

Future research should continue to explore possible statistical analyses of these data and should include effect sizes to assess the magnitude of the changes being seen. By incorporating measures such as correlations and effect sizes, the researchers will be better able to assess the strength of the relationship between CTC implementation and student perception and the relative size of changes in perception over time.

An additional limitation comes from the nature of the data available, which precluded examining additional potential outcomes of interest. Although this study investigated the relationship between CTC implementation and student perceptions, the CTC messaging might be expected to have an impact on various other outcomes of interest, such as general enrollments within engineering programs, and especially the enrollments of women and minorities. When schools use CTC to inform recruitment materials, it seems that enrollment outcomes would be of particular interest. Other potential outcomes of interest could be persistence, performance, and student satisfaction. Future research should examine the relationship between CTC usage and these additional relevant outcomes, and should seek to understand the ways in which CTC is affecting these outcomes.

Conclusions

This study examined the relationship between implementation of CTC messaging and students' changing perceptions of engineering among 14 schools. Data on the CTC messaging within a school was collected qualitatively from each school, while data on students' perceptions of engineering was collected from two large-scale online surveys (from 2008 and 2012) of undergraduate engineering students. This data was analyzed qualitatively by examining each school's unique implementation of CTC in relation to their survey results regarding changes in student perceptions of engineering.

Results suggest that schools that have utilized the CTC materials to a greater extent have seen a greater number of gains in student perceptions of the engineering field. Out of 14 schools examined, six showed evidence of strong adoption of CTC messaging along with significant increases in student perceptions of engineering. Additionally, four schools showed evidence of little to no adoption of CTC messaging as well as little to no improvements in student perceptions. Interestingly, four schools did not follow these patterns; three schools showed evidence of CTC implementation but no improvement in student perceptions, while one school showed no evidence of CTC implementation but had large improvements in student perceptions. Overall, 10 out of the 14 schools showed the pattern one would expect if CTC is related to improvement in student perceptions of engineering.

Additionally, after examining patterns of CTC implementation, it appears there is a trend towards greater improvements in engineering perceptions when CTC implementation occurs within courses or curriculum rather than only within recruiting and publicity materials. That said, we did not examine changing engineering perceptions among potential engineering students, and so it is unknown to what extent messaging in recruitment materials has impacted their perceptions. Current engineering students have more exposure to curricular modifications in their day-to-day activities, and thus are more likely to be impacted by messaging coming through the curriculum than recruitment activities.

Based on the number of student perception items with improvement among different groups, it seems as though the impact of the CTC messaging may be slightly less for women, although when men are examined separately from all students, no clear trend emerges. This indicates that the lower number of improvements seen for females may be simply a power issue and that CTC

messaging and principles are related to student perceptions similarly for men and women. It is interesting to note that a few schools in particular, notably School F and School N, saw many increases in student perception for females, even more than for all students combined. This variability among schools indicates that there are ways to improve student perceptions that seem to work differentially well for females, although our data do not allow us to identify exactly what those changes might be. Also, since School F had high CTC implementation and School N had little to no CTC implementation, it is not clear whether these improvements in student perceptions for females were related to CTC messaging and principles or not. Although evidence indicates that it is definitely possible to differentially improve the student perceptions of females with targeted interventions, future research should seek to identify which interventions are most effective. Our data indicate that the impact of CTC messaging does not affect students differentially by gender, but this finding is still tentative and should be further explored.

The trends for URM compared with non-URM students differ compared to trends identified by gender. Examining the URM students for each school, very few improvements in student perceptions were identified. In fact, out of all 14 schools, only three saw improvements for URM students at all. Comparing the findings for URM students to any other group, including non-URMs, females, or all students together indicates that more improvements were seen in every group for every school than were seen for URM students. This indicates that the CTC messaging and principles may be differentially affecting non-URM students. In addition, considering the consistency of this finding across all schools, it may be that improving perceptions for URM students is more difficult whether CTC is used or other improvements and interventions are used.

Overall, the implementation of CTC messaging, specifically its implementation in courses, seems to have been effective at improving student perceptions of engineering in this study. In-depth case studies of each of the successful schools would provide additional data to understand the conditions under which the CTC messaging can help change students' perceptions of engineering and therefore may impact student retention in engineering majors and their retention in engineering careers after graduation.

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