Culture and Attitude: A scholarship, mentoring and professional development program to increase the number of women graduating with engineering degrees.

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Abstract

Industry, media, and academia desire a more diverse engineering workforce. In response to those needs, faculty at South Dakota School of Mines and Technology (SD Mines) established the Culture and Attitude (C&A) program in fall 2010 with the support of a National Science Foundation S-STEM award. The program provides scholarships for academically bright and financially needy women, and also recognizes the need to change the fundamental paradigm (culture) for recruiting, and retaining students, particularly women, in engineering. To that end, the C&A program created a strong mentoring program, one that advocated a transformational approach to serving women in engineering. The program began as a collaboration between Metallurgical and Industrial Engineering programs and expanded to the Mechanical Engineering program in year 3. Students were required to meet with a mentor and their advisor at varied frequency throughout the semester based on their academic standing and class. They were also required to attend professional development activities, professional society meetings, and social activities with the entire C&A group once a month. The professional development and social activities included both technical (laboratory) and social (teamwork) confidence building exercises.

Program analysis was performed using traditional metrics (retention, the percentage of female enrolled and graduated) along with focus groups, longitudinal tracking, and examining student typology through Hermann Brain Dominance Inventory (HBDI). Students in the program were compared to the population that graduated from other engineering programs on campus. The retention, enrollment, and graduation rates of women increased in the initial five year period. Particularly noteworthy were the typology data, and focus group reactions to the program. HBDI results show that women at SD Mines think differently than their male counterparts, and majors with a greater percentage of women graduates received more than just the typical analytical engineering typology. C&A participants who received the scholarship in all three majors were more diverse in their typological preference. In other words, the participants were more entrepreneurial, highly detailed, empathetic engineers, a goal of the Engineer of 2020. Results from the focus groups showed that the professional activities were valued, but social activities were valued more. These findings became clearer in the focus group sessions where students indicated that the social activities allowed time for scholars to make social connections across academic disciplines. While much has been learned through approaching gender and intellectual diversity, much work remains before sustainable progress is made. Plans are now being developed to strengthen the program by incorporating service learning components as well as curricular changes for a broader institutionalization of the C&A program on campus.
Introduction

The number of female engineers has greatly increased since the 1980s, when less than 6% of engineers in the U.S. were women. However, female persistence in engineering has lagged behind that of their male counterparts. According to Joanne McGrath Cohoon, Associate Professor in the Department of Science, Technology, and Society at the University of Virginia, only 18-20 percent of engineering students in the U.S. are now women [1]. According to the Society of Women Engineers, women make up only 11 percent of practicing engineers. Furthermore, one in four females leave the engineering field after age 30, compared to only one in 10 male engineers [2]. In addition, other professional fields such as law and medicine have seen larger increases in women participation. Clearly, innovative approaches are needed to increase the participation of females in engineering and in STEM fields in general.

In 2009 the Culture and Attitude (C&A) team received an NSF S-STEM award [3] for program development. The award was designed to tackle many of the issues described above. The goal of the S-STEM proposal was to increase the number of engineers, especially women, on the South Dakota School of Mines and Technology (SD Mines) campus. Another ambitious goal was to create a campus-wide culture to support the growth of the female population on our STEM-focused institution. The program began as a collaboration between the Metallurgical and Industrial Engineering programs and expanded to Mechanical Engineering in year 3 of the program. The grant provided scholarships for students who had an unmet need not covered by family support, and the university provided mentors, advisors, and professional development activities.

The program was geared to prepare the scholars to graduate and be successful in the workforce or for pursuit of a graduate engineering degree. Key components to make women successful in engineering included helping the participants to be a) confident in their discipline, b) confident with their overall abilities and self, c) able to flourish in a diverse team environment, d) able to utilize their acquired engineering skills and e) life-long STEM learners. With the pending retirement of many of an aging engineering population, there is a unique opportunity for women to help broaden corporate diversity and change the corporate culture from within by utilization of the five above components.

The C&A program encouraged women to be successful by mentoring students with key individuals through their academic career, requiring them to partake in professional societies and in professional development. This paper covers the results and findings from the C&A program.

Activity/Mentoring Participation

All Culture and Attitude (C&A) scholars were required to sign a commitment letter indicating they would meet with regularly with the program mentor, and their academic advisor. In addition, each participant was required to join at least one professional society affiliated with their major, and participate in regularly scheduled society meetings. Students persisting to later years (after year 1) typically met less frequently with the program mentor, but focus group sessions indicated that scholars continued to value mentor accessibility, particularly at times of academic or personal stress.
The Program Coordinator, for the last two years of the program, has a varied background compared to most in academia. She was an engineering intern for Boeing Inc., Hutchinson Technology Inc., and Gateway; worked full-time for Merillat Industries, started her own business, has three kids, and now is an instructor in the Industrial Engineering Department. This multi-faceted background has proven valuable to the program. For example, in many of her private-sector experiences she was often the only female engineer and can directly relate to many of the situations the C&A scholars encounter. As such, she helps educate the scholars about the challenges ahead and how rewarding it is as an engineer, they make engineering processes more efficient and improve the quality of living for society. Thus, many of the C&A activities were focused on personal, real-life experiences, designed to increase scholar’s confidence levels.

The C&A program sponsored nearly 50 activities over the course of the first five years of the program. Activities included golf etiquette, glass blowing, rock climbing, and professional seminars. Professional activities were always valued, but social activities were perhaps valued a bit more strongly. The rationale became clear during the focus group sessions where students indicated that the social activities allowed time for scholars to make social connections across academic disciplines. A bar graph showing activities and participation levels for the last three years is shown below in Figure 1.
From Figure 1 it can be seen that scholars responded well to professional development activities that provided specific information on the program of complementary programs (e.g., orientation, research experience for undergraduates (REU) information). Scholars also responded well to activities that provided hands-on activities or social networking opportunities.
Scholarships

Over the five years, the Culture and Attitude program provided a total of 230 scholarships averaging $2,234 per student per semester. The program served a total of 70 students.

Traditional Metrics

By traditional metrics the program has been successful. Traditional metrics include percentage enrollment for women and persistence to graduation. The national average for women in engineering in general is roughly 17-21% [4]. However, it is also true that percentages vary somewhat by discipline. Female enrollment in engineering at SD Mines is well below this number. Over the five year period all three affected programs increased their female enrollment percentage. Targeted recruitment initiatives in the Mechanical Engineering program, which began well below 6% now has a female enrollment approaching 8%. Industrial Engineering began a program prior to the beginning of Culture and Attitude that focused on intellectual diversity. While the focus was predominantly on increasing complex problem solving skills with a customer focus, it also led quite naturally to better retention of women. The Industrial Engineering program has maintained a female enrollment of 25-40% women over the duration of the program. The Metallurgical Engineering program increased their female graduation rate from 17.5% to 25% during the five years of the C&A program.

While the statistics show a substantial bias towards female enrollment in Industrial Engineering, it is also recognized that Industrial Engineering is often viewed more gender friendly than most engineering majors. Nationally, 17% of engineers are women while women comprise 29.7% of Industrial Engineering majors. The relatively large number of Mechanical Engineering majors supported through the C&A program reflects the large size of the students in that major. At the conclusion of the C&A program, overall enrollments were approximately 580, 122, and 128 for Mechanical, Industrial, and Metallurgical Engineering majors. The overall number of women recruited and retained has increased over the five years of the C&A program. These gains are attributed to the overall C&A program, which includes other aspects such as focused heightened recruiting efforts, and individual departmental curricular initiatives. The graduation rates of women for each major for the five years before and during the S-STEM program are shown below in Table 1.

<table>
<thead>
<tr>
<th>Major</th>
<th>2006-10 (before program)</th>
<th>2010-15 (during program)</th>
<th>National %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME</td>
<td>5.4%</td>
<td>7.1%</td>
<td>13.2%</td>
</tr>
<tr>
<td>IEEM</td>
<td>33.0%</td>
<td>40.4%</td>
<td>29.7%</td>
</tr>
<tr>
<td>MetE</td>
<td>17.8%</td>
<td>24.6%</td>
<td>28.4%</td>
</tr>
</tbody>
</table>

An Institutional report for the American Society of Engineering Education reports that in 2011, 29.7% of all Industrial Engineering graduates were women, 13.2% of Mechanical Engineering graduates were women, and 28.4% of all Metallurgical and Materials graduates were women [4]. While Mechanical Engineering female enrollment remains below the overall national average, it is traditionally more difficult to attract and retain women in that major. Nevertheless, substantial
gains have been made over the last three years both in recruitment and in retention for all three C&A majors as shown in Table 1. The Industrial Engineering program has maintained a solid baseline of 39% female graduates. Current enrollments show a slight decrease in Industrial Engineering and a corresponding increase in Mechanical Engineering. This shift likely reflects a renewed interest by women in Mechanical Engineering or increased retention in that program as a result of the C&A program or both.

Of the 70 students who have participated in the C&A program, 23 (32%) of the participants have graduated, 11 (16%) left the program, and 36 (51%) remain persistent in their pursuit of a baccalaureate degree (see Table 2). Of the students who left the program, only five left because of poor academic performance.

Table 2. Status of Culture and Attitude students by major.

<table>
<thead>
<tr>
<th>Major</th>
<th>Students Served</th>
<th>Number Who Left</th>
<th>Number Who Graduated</th>
<th>Number of Active Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Engineering</td>
<td>28</td>
<td>5</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Industrial Engineering</td>
<td>31</td>
<td>4</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Metallurgical Engineering</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Other metrics from the C&A program include persistence to graduation. For that purpose a longitudinal group has been created for each fall during the years of the program from 2010-2015. Persistence towards graduation rates were compared between the C&A scholars and the control cohort groups, and that analysis is included in a following section.

Based on NSF Science and Engineering Indicators 2016, the National Girls Collaborative Project reports lower numbers of women in the workforce 15% for women in engineering in general with only 7.9% women in Mechanical Engineering and 17.1% women in Industrial Engineering [5]. Data for Metallurgical Engineering is not available. Thus, many of the C&A activities have also focused on gaining confidence in the workplace and developing life-long learning skills as mentioned above.

**Changing the Culture**

Prior SD Mines S-STEM research has demonstrated the utility of the Herrmann Brain Dominance Inventory (HBDI) to guide pedagogy and culture change associated with S-STEM disciplines, and therefore was utilized similarly for this project.

The HBDI typological model, shown in Figure 2, has a substantial research base with over a million participants in the multiple regression model and has been tested extensively for both reliability and validity [6]. Given these measures and the continued strong industry interest in effective team processes, the instrument is gaining in popularity as the industry instrument of choice [7]. Individuals with strong analytical abilities tend to dominate the blue quadrant,
individuals with a strong entrepreneurial or systems thought processes tend to dominate the yellow quadrant, individuals that are highly detailed or task oriented tend to dominate the green quadrant, and those that are nurturing tend to dominate the red quadrant.

Figure 2. Graphic depicting the four quadrants of the HBDI topological model.

Karlin and Kellogg demonstrated that there is a profound difference between thinking styles of male and female engineering students [8]. In this report they posit that the traditional engineering curriculum tends to focus on the analytical thinking style, which is in conflict with the thinking styles of many women and some men. Kellogg demonstrated that the distribution of students’ typology shifts from a greater diversity of thinking styles in freshman to primarily the analytical thinking style for graduating seniors. Kellogg also found that in a less traditional engineering program (Industrial Engineering, IE), that has a strong focus on intellectual diversity, the shift to a less intellectually diverse student body did not occur [9]. Even more compelling is that the Industrial Engineering program in question has an above average participation by women (39%), whereas a more “traditional” analytically-focused department on campus had both the significant shift in thinking styles and failed to retain a single female student in the studied population of seniors.

“What will the engineer of 2020 have? He or She will aspire to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright Brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and curiosity and wonder of our grandchildren.” That powerful quotation comes from the National Academy of Engineers Attributes of the Engineer of 2020 [10] that included the recognition that better innovation and complex thinking skills are needed for the next-generation of engineers. With regard to HBDI, this conclusion can be taken to mean that industry desires engineers that not only possess the technical skills required but who also possess attributes in the remaining typological quadrants.
Typologically women engineers do not, on average, think the same as their male counterparts. One function of the C&A program was to begin to fundamentally change the campus culture to help reflect these differences. Consider the typology for one of the engineering programs on campus as it relates to graduating seniors shown in Figure 3 (data collected in 2012).

![Whole Brain Model](image)

Figure 3. Typology of traditional engineering graduates.

From Figure 3, it can be noted that engineering graduates tend to be highly analytical, which has been the norm for the last 100 years. In all HBDI assessments for SD Mines blue circles denote male students and red circles denote female students. Data collected shown in Figure 3 for a specific department indicates that not only are the graduates highly analytical, there were no women graduates at the time the data was collected. This is typical of engineering disciplines and we posit that a typological mismatch may be a strong contributing factor as to why women leave engineering. While many women can successfully pursue engineering, it is equally true that the natural thinking preference for women is generally shifted downward and to the right. Consequently, traditional engineering curriculum does not address the natural typological preference for most female students. This phenomenon is gaining substantial support and collaborates with Felder and Brent’s landmark article on understanding student differences [11].

In terms of improving the campus culture to better accommodate female engineering students, the program has been highly successful. For example, Figure 4 shows the typology of women served in the C&A program (44 of the 70 students completed the instrument).
Figure 4 shows that not only are the participating departments able to recruit academically talented women, but through mentoring, social networking, and some curricular modifications they were able to retain women who tend to be more intellectually diverse than their male engineering counterparts.

While additional data needs to be collected, Figures 3 and 4 provide compelling evidence for necessary changes if one is to attract and retain qualified women in engineering. Recruitment is good but is not very helpful if one focuses solely on recruitment only to lose those same women later because of a curriculum heavily weighted in analysis. Similar results are noted by Felder and Brent [11] who note that, despite a common faculty misperception that students leave engineering because of poor academic preparation or fear of academic rigor, the reality is that the grade distribution of engineering students who leave engineering are very nearly identical to that of engineering students who persist to graduation. That is, students leave engineering because of other reasons, one of which seems to be a typological mismatch (Figure 3 and 4). This is particularly true for women who, while academically capable, are less likely to see value in a narrow analytical curriculum. A curriculum that provides options for women to engage in a broader societal context, in project planning functions, in creative design opportunities, or in entrepreneurial options is likely to lead to better retention. Indeed, results from this initial S-STEM grant has caused the investigators to see a broader array of design alternatives within the existing curriculum and is a focus of a follow-on grant.

**Longitudinal Tracking**

In addition to the C&A scholars, a cohort group was established for each fall term. To the extent possible, students selected for the control cohort were selected with similar academic backgrounds. A total of 70 C&A scholars and 71 cohort students were tracked each semester to include persistence in the program as well as academic success.

Of the 70 C&A scholars, a total of 23 have now graduated with an additional 36 remaining in the program. Of the 71 students in the control cohorts, 15 have now graduated, 12 have left the
university, and 44 remain. C&A scholars completed an average of 13.9 credits per semester whereas cohort students averaged 13.6 credits per semester. Of those students who graduated, C&A scholars averaged 10.2 semesters to graduation. Students in the control group averaged nine semesters to graduation. Although C&A scholars took as many credits as control students, they were also more likely to take a semester off to earn money (prior to scholarship support) and they were more likely to switch majors.

One of the objectives of the S-STEM program is to provide financial support for students so they could devote more time for studies. C&A scholars worked an average of 8.9 hours per week and maintained an average grade point average of 3.18. C&A tracking included semester-by-semester GPA and hours of external employment. A scatter plot of semester GPA earned for C&A scholars versus hours of outside work is shown in Figure 5.

![GPA vs Hours Worked](image)

Figure 5. Average Semester GPA for C&A Scholars Versus Hours per Week Worked.

Figure 5 indicates that there is little correlation between semester GPA earned and hours of external employment (correlation is positive 0.015). There is a congregation of data points at no external hours worked indicating that scholarship support is critical for a number of these students. Furthermore, there seems to be a downward shift of external employment for C&A scholars. Unfortunately, no similar data was collected for control group students so no formal comparison can be made.

**Focus Groups**

The Program Evaluator met periodically with C&A scholars over the period of the grant. At the conclusion of the grant, the evaluator met with 27 of the C&A scholars in two formal focus group sessions. All C&A scholars were invited to participate but it was made clear that participation was not required. Ideally focus group sessions would consist of 7-10 scholars, but no interested scholar was turned away. Because of logistical considerations, we split the participants into one of two groups. Each focus group session lasted 1-1.5 hours. All scholars signed IRB informed consent
forms and were informed that sessions would be recorded but that comments would be generalized for a report to the investigators. Under no circumstance would the evaluator share individual comments to either the program mentor or the program investigators. The evaluator posed questions related to social and professional development activities, external work, mentoring, and areas for improvement.

Both sessions were lively and scholars provided useful input on a variety of topics. Among the useful feedback is that scholars felt the social activities were important because it allowed them to connect with scholars in other disciplines. While it occurs somewhat naturally in the normal university environment, social networking allowed for a more natural connection through a common bond that is both gender and program based. Specifically, the scholars made additional friendships with individuals outside their comfort zone. Finally, the participants specifically noted the vertical integration that occurred with older scholars helping to mentor some of the younger scholars. The more academically experienced scholars enjoyed the mentoring role and the younger scholars enjoyed the opportunity to seek additional academic advise that faculty advisors may not be able to give; specific instructors, etc. When queried as to the types of activities they most valued, the participants seemed to enjoy a breadth of activities but seemed to migrate to hands-on laboratory activities.

While many of the scholars felt a need to continue to work outside of school they also noted that hours worked prior to scholarship support was more likely to be closer to full time than the part time. (The average hours devoted to external work dropped to less than 10 hours per week). They noted that fewer work hours also gave them greater flexibility in their schedules.

The evaluator specifically asked the question if the mentoring role should or could be left solely to a department advisor. They were unanimously opposed to this. First and foremost, they noted that mentoring and advising are two separate functions and appreciated each for their specific roles. In particular, they were very comfortable with the program mentor and mentioned the importance of the mentoring role. A few participants mentioned that they may not have persisted in the program had it not been for the mentoring support. Asked if the role could be accomplished by a male, they were opposed to it. While they mentioned that many of the male faculty members involved are very supportive, they also noted that having an individual that understood their issues at a more personal level was important. Asked if the mentoring role could or should be distributed to be more departmentally specific, they mentioned it could be, but also noted that it would not be very efficient and they really enjoyed the cross disciplinary interaction of the social and professional development activities.

The last area covered in the focus group sessions was that of areas for C&A program improvement. The students expressed interest with more external professional development support such as networking at national conferences and workforce development (finding internships and permanent employment).

A Scholar’s Perspective

To help reflect the C&A program we will offer the actual experience of one of the scholars, Belinda (name fictitious). Belinda began her academic career in 1990 and, while she performed well
academically, she did not find value in her program because she saw difficulty relating her studies to the real world or the kind of career that she would find reward. Belinda is now married and has two sons ages 11 and 17, one of whom has special needs. Belinda returned to college in the Fall 2010, and found balancing her studies with that of home life very difficult. She qualified for federal work study but the financial constraints meant that completing a degree would be difficult. With departmental and C&A scholarship support she was able to complete her degree in Industrial Engineering and graduated with honors. When asked about the benefits of the C&A program she noted that she might not have completed the degree without that support. Belinda also noted that the support meant less stress in her personal life but more importantly, she could better connect to campus life and to other C&A scholars because of that support. The C&A program allowed Belinda’s academic studies to become enriching rather than just a means to enter the professional work force. Belinda now is working full-time as an engineer utilizing her degree.

**The Road Forward**

While much has been learned through the C&A program, much work remains before sustainable progress is made. Cultural paradigm shifts take time in industry, under the best of circumstances, and the same is true in academia. In fact, because of limited resources and conflicting objectives, cultural shifts typically take longer in academia. In terms of sustainability the C&A program received support from a private foundation, and beginning in the fall 2016 received additional support from the National Science Foundation [12]. Future C&A program plans include incorporating service learning components, additional curricular changes, and program expansion beyond the three aforementioned programs (Industrial, Mechanical and Metallurgical Engineering).

**References**


