Work In Progress: Engineering Faculty and Role Models

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Engineering Faculty and Role Models: A Work in Progress

Abstract

The impact of role models in inspiring individuals to achieve their life goals is widely discussed in literature. Role models are known to support retention, recruitment, and sense of belonging in STEM and engineering disciplines. College faculty members, and particularly those with identities with limited representation in STEM, such as women faculty members and faculty members of color are known to play a key role in enrollment and performance of students sharing their identities. Given what is known about role modeling, this study aims to explore the perceptions of engineering faculty members about their own function as role models for future generations of STEM professionals. Furthermore, we explore the role models that inspired current engineering faculty members to choose their paths. In this regard, we aim to assess role models (media or real-life individuals) that influenced the current engineering faculty members' identity development. Our research questions are: 1) What kind of role models did current engineering faculty members have while growing up? 2) How do these beliefs and experiences about role modeling vary across gender and race/ethnicity? 3) Do existing engineering faculty members consider themselves as role models? and 4) How often and in which areas do engineering faculty members believe they support the growth of their students as role models?

To answer our research questions, we collected faculty members' responses through an ongoing anonymous survey of engineering faculty members distributed across the 30 largest engineering universities in the US. To analyze data we used descriptive statistics and qualitative analysis for open ended questions. The results showed that characters in STEM related TV shows inspired the majority of the faculty members followed by science fiction movies and popular scientists respectively. Men, in comparison to women, were more inspired by role models from all categories. Teachers and family members were considered as the greatest source of inspiration and encouragement to pursue a STEM career by both men and women. Furthermore almost 88% of the current engineering faculty members consider themselves as role models. The data indicates that while faculty members support students' growth in technical skills and professional behaviors, little support is offered for wellbeing practices, emotional understanding, and socially responsible beliefs. We expect the findings of the study would bring new insights into the role modeling practices for development of engineering identity among younger generations.

Introduction

There has been a considerable focus on promoting diversity in the STEM workforce in recent years. Despite this, people of color, particularly Black and Hispanic groups, remain severely underrepresented [1]. Similarly, women, though widely represented in healthcare related science professions, remain underrepresented in computing and engineering fields [1]. These disparities in the workforce are tied to underrepresentation of women and people of color in STEM and engineering fields in American higher education. In terms of gender gap in engineering graduates, women comprise only 21% of engineering majors and only 19% of computer science majors [2]. Likewise, Black students earn only 7% of STEM college degrees while Hispanic

college graduates earn only 12% of STEM college degrees, both numbers being much lower than the share of these demographics in the total American population [1].

Interventions aimed at remedying the STEM gender gap are based on the belief that the female students interested in pursuing STEM majors in college are discouraged due to a lack of same-gender role models [3]. While research highlights that having female or minority professors for STEM subjects inspires students to pursue STEM degrees [4] the absence of role models poses a serious challenge. Research indicates that women and minorities not only continue to be considerably underrepresented in faculty positions in science and engineering departments, they are also not getting faculty positions despite completing graduate degrees [5]. As a result, women and minorities at the undergraduate level lack similar demographic faculty role models and mentors.

Given what is known about role modeling, this study aims to explore the perceptions of engineering faculty members about their own function as role models for future generations of STEM professionals. Furthermore, we explore the role models that inspired current engineering faculty members to choose their paths. In this regard, we aim to assess role models (media or real-life individuals) that influenced the current engineering faculty members' identity development in an effort to gain new insights into the role modeling practices for development of engineering identity among younger generations.

Literature Review

The positive impact of role models has been abundantly discussed in the literature. Studies indicate that having a female professor for STEM subjects inspires female college students to pursue STEM degrees [4], [6]. For instance, Rask and Bailey [6] investigated the role models' effect on women and men from minority groups using micro-data involving transcripts, student records and faculty members records, from 1988 to 2000 from Colgate university. The results showed that the proportion of classes taken with a faculty member that students shared their identity with had a positive effect on the probability of students choosing that major. In addition, Sonnet et al [7] also found a positive association between the percentage of women in faculty positions and percentage of women in undergraduate science and engineering majors, indicating that faculty members exert a role model effect on women and minority students in STEM and engineering.

Interaction with female role models is known to influence female students' implicit cognition about, and their grade performance within STEM disciplines. For instance, Young et al. [8] examined undergraduate science majors' interactions with female role models. The findings revealed the existence of both direct and indirect paths between career aspirations of women and implicit cognition. Furthermore, in instances where female professors were viewed as role models, female students identified with science and stereotyped it as feminine indicating that viewing professors as role models is associated with science-based career goals for both genders. Additionally, Johnson, I. Y. [9] investigated how exposure to female role models influences student achievement at college level. The findings revealed that female faculty members

positively influence female students' grade performance while not affecting male students' performance.

The relationship between female students' retention, self-efficacy, and sense of belonging with access to role models is also explored in the literature. For instance, Robst et al. [10] investigated the relationship between female students' retention rate in the first year and the percentage of science and mathematics classes taught by female faculty members. The results found a positive relationship between the percentage of female faculty members teaching science and mathematics classes and the retention rates of female students in their first year of college. Similarly, Johnson, I.Y. [11] investigated the effect of having a female instructor, self-efficacy, and their interaction on male and female student grade performance by conducting a survey. The results revealed a significant positive relation between self-efficacy for self-regulated learning as well as academic success. In addition, exposure to role models is also known to improve STEM as well as non-STEM students' sense of belonging [12]

Bettinger and Long [13] investigated whether faculty members serve as role models and whether the gender of the instructor had any effect on female students based on the data obtained from 12 public colleges of Ohio, consisting of student records, transcripts, and demographics. The study also gathered data for full time faculty members. To examine whether there is an effect of instructor gender on female students, the study considered three outcomes: whether the students took any additional courses in the discipline after their first course with female faculty members, the total number of subsequent credit hours taken after the course, and the choice of major. The study found that female faculty members had the potential to spark students' interest in a discipline particularly for mathematics, statistics and geology, sociology, and journalism. However, the impact for engineering, physics and computer science remained statistically insignificant. This points to the further need for investigating the impact of female faculty members as role models for engineering majors.

Similar to the impact of female role models on women in STEM, the impact of role models with the same race/ethnicity as that of the minority students has shown to be very encouraging. For instance, in a study conducted by Allen and Collisson [14] predicting whether minority students exposed to role models of the same race/ethnicity were likely to enroll in the institution and make similar professional choices. The findings confirmed that minority students were indeed more willing to make the same career choices as the role models who shared their racial/ethnic identity. Similarly, a study by Newman, C.B. [15] exploring the experiences of African American engineering students found that faculty members have a strong influence in encouraging or discouraging African American engineering students to continue in their major. While positive student experiences with faculty members in research labs and recommendations allow students to practically understand their coursework, the faculty members can also have an equally negative impact on African American students' academic and personal lives.

Intervention programs aimed at promoting female participation through role models have also proved to be encouraging. For instance, Hernandez et al., [16] explored the effectiveness of PROGRESS, a program focused on providing mentoring and role modeling to undergraduate women interested in the STEM degree, and careers. The result showed that the female students

involved with PROGRESS identified more female STEM career role models than the control group. In another study, Fuesting and Diekman [17] focused on exploring the impact of role models on communally oriented students. The results of the study found that communally oriented students were more likely to admire others in Math and Science. The students preferred hypothetical STEM advisors enacting communal behaviors. In addition, the importance of communal behavior of actual role models depended upon students' own communal orientation. Thus, it can be argued that interaction with role models in STEM and advisors can be a way to attract students to STEM disciplines.

While multiple research studies have pointed out the fact that faculty members can serve as role models for women and minority students, little research has explored the role models for existing faculty members. Insights about the existing faculty members' role models will help us understand effective role models, their characteristics and impact. In addition, evaluating how faculty members support their students will enable us to understand effective role modeling practices. Based on the gaps identified in the literature, we pose the following research questions.

1) What kind of role models did current engineering faculty members have while growing up?

2) How do beliefs about role modeling vary across gender and race/ethnicity?

3) Do existing engineering faculty members consider themselves as role models?

4) How often and in which areas do engineering faculty members believe they support the growth of their students as role models?

Theoretical Framing

In this study we frame role modeling in light of the motivational theory of role modeling (MTRM) presented by Morgenroth et al. [18]. The motivational theory of role modeling describes role models as "individuals who influence role aspirants' achievements, motivation, and goals by acting as behavioral models, representations of the possible, and/or inspirations" [18]. Based on this conceptualization we define role models as individuals who epitomize certain behaviors, goals and strategies that are desirable for the people exposed to them (aspirants) such that they tend to imitate them. By adhering to the conceptualization of role models as indicated in the MTRM, we believe that role models, besides possessing key attributes that make them effective at what they do, exert considerable influence on aspirants by inspiring them and shaping their behaviors, choices, and goals.

Methods

In this study we examine the types of role models that inspired engineering faculty members in top American engineering universities. We explore how the faculty members' beliefs and experiences about role modeling vary across gender and race. In addition, our goal is to investigate the professional domains/areas in which engineering faculty members believe they support the growth of their students as role models. Our focus on exploring faculty members' support in students' growth is framed under the motivational theory of role modeling presented

by Morgenroth et al [18] in a sense that such support could help develop their engineering identity and self-efficacy.

To inform our study, we collected faculty members responses through an ongoing anonymous survey of engineering faculty members distributed across the 30 largest engineering universities in the US. This work in progress is part of a larger study that aims to assess gender bias faced by engineering faculty members.

Participants

The survey was administered to both tenure track and teaching focused faculty members employed in all engineering departments of the top 30 largest engineering universities in the US (list of universities is attached in the Appendix). A total of 161 participants responded to the survey out of which 134 participants completed the section related to role models. In terms of gender, among the 134 participants, 66 identified as women, 63 as men, 2 as gender non-conforming queer, 1 as non-binary and 2 preferred not to answer. In terms of race, 99 faculty members identified as White, 2 as Black, 3 as Asian Indians, 7 as Chinese, 2 as Korean, 11 as mixed of two or more races, 3 as other Asians and 7 as other race.

Survey

The survey section on role models consisted of 16 questions based on Likert scale with 5 answer options ranging from strongly disagree/never to strongly agree/always for different question types. The first section of the survey aimed to acquire information on participants' experiences while growing up with respect to role models in their life as well as those from popular media that supported their interest in STEM careers. However, questions exploring types of role models provided 4 broad options i.e., 1) characters in science fiction films, 2) characters in STEM related TV shows, 3) Popular STEM scientists and 4) none of these. In addition, the survey asked participants to mention their STEM role models other than the ones mentioned in the answer choices.

Moreover, the survey asked the participants to rate the extent to which they considered themselves to be the role models for the future generation of engineering students. The question was followed by asking participants to rate how often they intentionally supported their students' growth in the following areas i.e., technical knowledge, professional behaviors, equity and inclusion practices, wellbeing practices, socially responsible beliefs and practices and emotional understanding and management. Lastly, the survey asked an open-ended question to allow any further input from the participants.

Results

Types of role models

In our first research question we explored the type of role models that inspired the current engineering faculty members to pursue an academic career in engineering. Table 1 shows each category of role models against the number and percentage of faculty members who reported being influenced by a role model from that category. Table 1 indicates that STEM related TV

shows inspired 109 (81.3%) faculty members followed by characters in science fiction movies which inspired 105 (78.4%) faculty members. In addition, 98 (73.1%) faculty members chose popular STEM scientists as their source of inspiration, while 59 (44%) faculty members selected "none of these".

Table 1

Role models that inspired the existing engineering faculty members

Role Models	Number (%)
Characters in Science Fiction movies (e.g., Star Trek, Contact, Species, Planet of the Apes etc.)	105 (78.4)
Characters in STEM related TV shows (e.g., Mac Gayer, CSI, Futurama, The X Files, Dr. Who etc.)	109 (81.3)
Popular STEM scientists (e.g., Marie Curie, Stephen Hawking, Katherine Johnson, Neil Armstrong etc.)	98 (73.1)
None of these	59 (44)

We also analyzed potential role models across gender and race. Participants were provided four broad choices i.e., characters from films, characters from STEM related TV shows, popular STEM scientists and none of these. Participants were allowed to select multiple options. Table 2 and Table 3 present the role models across gender and race respectively. Data analysis indicates that across genders men were comparatively more inspired by characters in science fiction movies, STEM related tv shows and popular STEM scientists. Only 30 (47%) of the men selected "none of these" responses. Women on the other hand were less inspired by the options provided and 42 (63.6%) women faculty members selected the option "none of these".

Table 2
Role Models across gender

	Characters from Science fiction movies (%)	Characters from STEM related TV series (%)	Popular Scientists (%)	None of these (%)
Men	21 (33)	17 (27)	20 (31)	30 (47.6)

Women	7 (10.6)	7 (10.6)	16 (24.2)	42 (63.6)
Gender Non-conforming queer	1 (50)	2 (100)	2 (100)	1(50)
Non-Binary	1(100)	1(100)	1 (100)	1 (100)
Prefer not to answer	0	0	0	2 (100)

Additionally, we asked participants an open-ended question, asking them to share the role models (from real life or popular media) that encouraged them to pursue a STEM career. We conducted a qualitative analysis of the open-ended responses and found 7 broad themes namely real-life STEM professionals (NASA employees), famous STEM scientists, family members, teachers/professors, film and TV characters, books (fiction/non-fiction), and no role models. Across gender we found no differences in terms of role models. Both men and women considered teachers at various levels of school to be the biggest source of inspiration, followed by family members (parents, grandparents, uncles, aunts), real life STEM professionals (NASA employees), film/tv characters, famous STEM scientists, books, and no role models respectively.

The survey participants were spread across eight different ethnicities that we categorized as White, Black, Asian Indian, Asian Chinese, Korean, Mixed Race, Other Asian, and Others. The results followed a similar pattern across races where the majority of faculty members from each race except for Asian Indians selected “none of these” over the other categories. The next popular role model category was popular scientists followed by characters in STEM related TV shows and characters from science fiction films. Table 3 shows the distribution of faculty members role models across race.

Table 3
Role Models across race

	Characters from Science Fiction movies (%)	Characters from STEM related TV series (%)	Popular scientists (%)	None of these (%)
White/European American	24 (24.2)	19 (19.2)	28 (28.3)	54 (54.5)

Black/ African American	2 (100)	2 (100)	2 (100)	2 (100)
Asian Indian	3 (100)	3 (100)	2 (66.7)	1 (33.33)
Asian Chinese	1 (14.3)	1 (14.3)	3 (42.9)	4 (57.1)
Korean	2 (100)	2 (100)	1 (50)	1 (50)
Two or more races	1 (9.1)	3 (27.3)	1 (9.1)	7 (63.6)
Other Asian	1 (33.33)	3(100)	3 (100)	2 (66.7)
Other Race	2 (40)	2 (40)	5 (100)	3 (60)

Faculty members' support of students' growth

To understand faculty members' support of student growth in different areas we first explored whether they consider themselves role models for engineering students. In this regard, we asked them to tell us the extent to which they considered themselves as a role model for their students. The options were "not at all", "very little", "somewhat", and "to a great extent". The data indicates that most faculty members (88.8%) answered "to a great extent" and "somewhat" in identifying themselves as role models to the engineering students while 11.2% indicated that they did not identify as role models.

As Nelson [5] reported that female STEM students hesitate to join faculty members after graduation, we felt it was important to study the impact of faculty members role models on students while they are in college. We explored how often the existing engineering faculty members offer support to students in different areas of growth. In this regard, we calculated the number of times faculty members supported their students. The response options included never, rarely, about half the time, most of the time and always. Table 4 shows the frequency distribution of the faculty members' responses.

Table 4
Faculty members' support of students' growth as role models

Students' growth areas	Never (%)	Rarely (%)	About half the time (%)	Most of the time (%)	Always (%)

Technical Knowledge and Skills	2 (1.5)	0	6 (4.5)	41(30.6)	85 (63.4)
Professional Behaviors	0	2 (1.5)	11(8.2)	52 (38.8)	69 (51.5)
Equity and Inclusion practices	0	5 (3.7)	15 (11.2)	56 (41.8)	58 (43.3)
Wellbeing practices	1 (0.7)	12 (9)	41 (30.6)	51 (38.1)	29 (21.6)
Socially responsible beliefs and practices	3 (2.2)	23 (17.2)	34 (25.4)	43 (32.1)	31 (23.1)
Emotions understanding and management	5 (3.7)	25 (18.7)	33 (24.6)	42 (31.3)	29 (21.6)

The survey sheds a light on faculty members' support of students across different areas of growth. faculty members' support was highest in technical knowledge and skills where 85 faculty members (63.4%) expressed that they always supported their students in this area. The second highest level of support was found for professional behaviors where 51.5% (69 participants) indicated that they always supported students in this area. Support in equity and inclusion practices was also found to be high with 58 participants selecting always.

In contrast, emotional understanding and wellbeing practices remain the least supported area of students' growth by the faculty members where only 29 faculty members (21.6%) indicated that they always supported their students in these areas. The second least supported area of growth is socially responsible beliefs where only 31(23.1%) faculty members expressed that they "always" supported students in this area.

Discussion

Literature indicates that depiction of STEM professionals in the media not only influences the students' stereotyped perceptions of STEM but also influences their participation in STEM fields [19]. Moreover, the depiction of inspirational STEM characters in media, particularly films, can lead to improvements in STEM identity development among students [20]. Therefore, it makes sense that the majority of the engineering faculty members surveyed were inspired by STEM related TV shows and popular films while growing up. The results of this study are also consistent with previous studies that suggest parents and teachers as major factors influencing the STEM career interest in students [21], [22].

Previous studies have explored relationships between female and minority students' retention, self-efficacy, and sense of belonging with role models and found a positive impact of role models in pursuing STEM fields of study [9], [10], [23]. However, the impact on specific areas of growth for students within STEM fields has not been studied before. One unique aspect of this study is the exploration of faculty members' support in different areas of students' growth within engineering discipline. This exploration is a step towards exploring faculty role models' effect on engineering students' identity development.

The theoretical conceptualization of role models under the motivational theory of role modeling (MTRM) [18] considers that role models epitomize certain behaviors desirable for the people (aspirants) such that they tend to imitate them. Given the results of this study indicating that engineering faculty are least supportive of students' emotional understanding and wellbeing practices, we can speculate that the future generation of engineers might imitate this behavior and contribute to the existing high stress culture within engineering.

Limitations and future directions

One of the limitations of this study is the descriptive nature of this paper which does not explain the cause of the explored relationships. Future work should focus on using advanced quantitative or qualitative methods to determine why certain individuals serve as role models. In addition, the limited sample size may not be representative of the entire engineering population. Future work could address this limitation by conducting a larger study that includes a more diverse population of engineering faculty members. Moreover, it would be interesting to see qualitative explorations aimed at understanding role modeling practices for student support within STEM disciplines.

Conclusion

This study aimed to explore the role models that inspired the current generation of engineering faculty members and explore their perceptions about their own function as role models for the engineering students. The survey data was analyzed using descriptive statistics while open-ended responses were qualitatively analyzed to understand the role model inspirations of faculty members. The results showed that characters in STEM related TV shows inspired the majority of the faculty members followed by science fiction movies and popular scientists respectively. In terms of gender, more men were inspired compared to women by role models from all categories. However, the qualitative analysis of the open-ended self-reported role models found no differences across gender. Teachers and family members were considered as the greatest source of inspiration and encouragement to pursue a STEM career by both men and women. Furthermore almost 88% of the current engineering faculty members consider themselves as role models. The data indicates that while faculty members support students' growth in technical skills and professional behaviors, little support is offered for wellbeing practices, emotional understanding, and socially responsible beliefs.

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Appendix 1

Table 1

List of institutions surveyed

1	Georgia Institute of Technology
2	University of Illinois at Urbana-Champaign
3	Texas A&M University
4	University of Michigan
5	The Pennsylvania State University
6	Massachusetts Institute of Technology
7	Virginia Polytechnic Institute and State University
8	North Carolina State University
9	Purdue University
10	Arizona State University
11	Florida Atlantic University
12	University of Florida
13	The Ohio State University
14	Stanford University
15	University of Washington in Seattle
16	Rensselaer Polytechnic Institute
17	Cornell University
18	The University of Texas at Austin
19	University of California, Berkeley
20	Clemson University
21	University of California, San Diego
22	University of Notre Dame
23	University of Minnesota -Twin Cities
24	Michigan State University
25	Iowa State University
26	University of Utah
27	The Johns Hopkins University
28	University of Wisconsin-Madison
29	Northwestern University
30	University of California, Davis