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Advancement of Women in Engineering: Past, Present and Future

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Dr. Chathapuram Ramanathan, Phd., ACSW, LMSW, LMFT, CAC has worked in the human service area for over three decades, and is an Associate Professor and former Chair of the Social Work Department at the University of West Florida. Dr. Ramanathan graduated with a Masters and a Doctoral degree from the University of Illinois. His doctoral degree is in Social work and Human Resources Management. He also has a MA in Medical and Psychiatric Social Work from Madras School of Social work. His practice and scholarship focus is on cross-cultural issues, social work practice, social development, addiction recovery, corporate social responsibility. Dr. Ramanathan has been providing Psychotherapy services for over 35 years, is a Licensed Marriage and Family Therapist, and a Licensed Clinical and Macro Social Worker. Prior to that, in the State of Illinois, he provided social work services for 12 years. Over the years he has been providing clinical supervision and case management consultations. Dr. Ramanathan is a credentialed Military Family Liaison Consultant.

Dr. Ramanathan has taught full time in schools of social work for over 17 years (Fulltime equivalent), about six years as Associate Professor. He has published over 35 refereed articles, book chapters, and co-authored three books. His book published in 1999, is called All Our Futures (Foreword written by Dean Shanti Khinduka). The book All our Futures was reprinted in 2004. Dr. Ramanathan co-authored another book in 2011, titled Human Behavior in a Just World: Reaching for Common Ground (Foreword written by Dean Frank Raymond). Another co-authored and co-edited book titled: Governance, Development, and Social Work was published in August 2013 by Routledge (Foreword written by Dean Emeritus and Prof. Jim Midgley). An Asian Edition of the book Governance, Development, and Social Work was published in January 2014 by Rawat Publishers. Yet another co-authored and co-edited book titled: Spirituality, Culture and Development was published in October 2016, by Lexington Books (Foreword written by Dean Emeritus and Prof. Kay Hoffman). In 2011-2012 (October 1, 2011 to March 30, 2012), Dr. Ramanathan was conferred with Fulbright-Nehru Visiting Scholar award, and NIMHANS (National Institute of Mental Health and Neuro Sciences) served as host institution. In 2004, he was conferred a Fulbright Senior Specialist award to lecture on Social Work as a Full Professor, to students and professionals, at the Tata Institute of Social Sciences, a Deemed University, (first social work program in Asia - established 1936); and at the National Institute of Mental Health and Neuro Sciences. Dr. Ramanathan is an American citizen of Asian Indian origin. Dr. Ramanathan was Co-Director, Social Work Theory and Practicum in the Context of India, Office of Overseas Study and School of Social

Work, Michigan State University, East Lansing, MI - 48824, July 1991- to August 1992, and taught students from the Midwestern States of the USA. This was a very successful program. In 2013, Dr. Ramanathan organized an overseas study for upper class undergraduate students and two faculty members from Simpson College, Iowa. In 2013, Dr. Ramanathan facilitated a co-sponsored conference on Human Rights and Sanatana Dharma: Implications for Global Citizenship. The conference was co-sponsored by Simpson College, Iowa and Karnataka Samskrit University, Bangalore, India. Dr. Ramanathan has presented several key note and plenary speeches in conferences. Most recently in January 2014, he presented a plenary in a conference titled "Bounds of Ethics." The inaugural address in that conference was given by his holiness the Dalai Lama. Dr. Ramanathan served a three year term on NASW's National Committee on Racial and Ethnic Diversity, and his term ended in June 2015. He has served NASW's National Ethics Committee from 2007-2009. He serves on the editorial board and as a board of manager of two major journals: Drugs and Society; Social Development Issues. Dr. Ramanathan serves as the North American Representative of the Indian Society of Professional Social Workers (ISPSW). Dr. Ramanathan, facilitated a Memorandum of Understanding between NASW and ISPSW, for the first time in the history of these professional organizations. He has been serving as Social Work Peer Review Committee Member, Fulbright Specialist Program, since January 2016. Dr. Ramanathan has received many awards and honors, including a tribute from a Michigan Legislator and Michigan Governor, in October 2008, which recognized him as an important Asian American leader. One of his co-authored articles was recognized as the best article, by the National Human Rights Workers Association. This article appeared in the Journal of Inter-group Relations, and is titled: Mental health, social context, refugees and immigrants. In 2002, Dr. Ramanathan was a speaker through the US-Speaker Series program, presented "Diversity and Inclusiveness: A Hindu American View," at the conference "Religious Pluralism and Democratic Societies: United States and South East Asia," Kuala Lumpur, Malaysia. In the late 80s and early 90s, Dr. Ramanathan served on Michigan Governor's Multi Cultural Mental Health Education Task Force. Dr. Ramanathan served the Council on Social Work Education's (CSWE) International Commission from 1992-2004. He has been serving CSWE as a trained site visitor for over 20 years, reviewing graduate and undergraduate programs for accreditation. He has served on several agency boards, including the board of American Citizens for Justice. Dr. Ramanathan has presented over 50 papers and workshops in 18 countries, including the U.S., Canada, South Africa, Portugal, Singapore, Malaysia, Netherlands, the U.K., Turkey, India, Sri Lanka, Thailand, Ireland, Germany, Poland, Brazil, Hong Kong, and Bangladesh. Dr. Ramanathan has trained participants in addiction recovery, clinical social work, as well as on social development issues. Also, Dr. Ramanathan has trained participants in the area of Diversity Issues through many organizations, such as the University of East London; National Human Rights Workers Association; Larsen & Toubro, LTD; Phillips Software LTD; National Association of Social Workers – Michigan Chapter; Southfield School District, Michigan; Plymouth – Canton Community Schools, and so on. NASW News Appearances: 1) July 2012, Volume 57, # 7. 2) June 2013 NASW News: http://www.socialworkblog.org/nasw-news-article/2013/06/nasw-signs-mou-with-indian-society-of-professional-social-workers/ https://www.socialworkers.org/pubs/news/2013/06/social-work-in-action.asp 3) September 2015 NASW News – Social Workers discuss ways to undo racism https://www.socialworkers.org/pubs/news/2015/09 racism.asp

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Abstract

Globally, gender gap has persisted over the years in Science, Technology, Engineering and Mathematics (STEM) disciplines. Among the STEM fields, engineering continues to have one of the highest rates of attrition (40%). Reasons suggested for low female graduation rates include, lack of female engineering role models, misconceptions of what it is like to be an engineer, and having fewer technical problem-solving opportunities through K-12 compared to males. Lack of confidence is another critical issue that results in female engineering students switching majors. Therefore, designing and developing policies to tap into the potential of women and their contribution in this vital sector, requires understanding of how gender is related to participation, and success.

Historically, in the development field, societies were viewed from a deficit perspective, as opposed to strength. Societies were classified as developed, under-developed, and least developed; or first world, second world, and third world. There is need to rethink categorizing nation states in value-laden terms and use value free terms to categorize nations, **as this likely to produce an ethos which promote reciprocity in learning, and foster understanding the reasons for higher percentage of women in engineering.** Nations such as India, Turkey, Tunisia, Sri Lanka, Mozambique, and Singapore, have achieved a greater number of women in the STEM fields.

The above background motivated the authors to investigate the participation of women in engineering, to study facilitators and barriers for women entering the field of engineering and its implications for education. In this regard, the main research questions of this study are

- What are the main reasons women are interested in engineering?
- What are some barriers to women developing an interest in engineering?
- How can more young women be encouraged to develop an interest in engineering before enrolling in college? and
- What are the issues that are critical to recruitment and retention of women in engineering and how to develop strategies to overcome them?

To answer the above questions, a survey was designed and administered to undergraduate students in engineering at the university where the authors are employed. Purposive sampling was utilized to collect information on why students were interested in engineering and the barriers the students and their friends encountered. The authors use the survey results in identifying initiatives to attract and increase the number of local female high school students wanting to pursue engineering as a career, and provide pointers to develop intervention strategies that may help retain them. It is anticipated that the information obtained through this descriptive study would guide educators and researchers in attracting middle and high school female students to consider engineering as a major in college.

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Introduction

Gender inclusiveness in the field of engineering has been a challenge over the decades, at times regressing, yet evolving. The number of women in engineering fields is not globally uniform. Some parts of the world have been more inclusive of women in engineering compared to others. Historically, in the development field, societies were viewed from a deficit perspective as opposed to strength. Societies were classified as developed, under-developed, and least developed; or first world, second world, and third world. There is need to rethink categorizing nation states in value-laden terms, as this would increase reciprocity in learning [1]-[3]. Some nations such as India, Turkey, and Singapore, have a greater number of women in the STEM fields [4][5]. Having a paradigm shift in contemporary perspectives that classifies societies as "First and Third World" may provide opportunities to observe and learn **from nations with an open mind**. **While these nations are successful in recruiting and retaining women in engineering, study of what makes it difficult for women in the economically advanced nations such as those in the European Union and the US, and implement similar strategies after having a solid grasp of those strategies that will cause this evolution possible?** Finding an answer to these questions was the motivation behind this research work.

According to Briseno [6], many female students in developed countries today select advanced mathematics and science courses and are encouraged to pursue careers in engineering and technical fields. Historically, most women who paved the way for others to enter these professions neither had the opportunities nor support on their side. Nevertheless, they introduced several initiatives that created opportunities for other women by "shaking up the world of science in all sorts of groundbreaking ways" [1]. In the past few decades, there is overwhelming evidence that women are underrepresented in engineering worldwide [7], [8]. On average, women constitute "less than 10% of engineers worldwide, so they stand out of most engineering crowds" [9].

Presently, STEM disciplines attract fewer female students compared to other majors due to low interest in STEM related subjects while at school, which leads to fewer women being employed in the field of technology and engineering. This results in under-representation of women in these fields. [10]. Women with STEM degrees are less likely than their male counterparts to work in a STEM occupation; they are more likely to work in education or healthcare [11], [12]. Women and racial minorities hold fewer than 25% of STEM jobs requiring a college education and 9% of underrepresented minorities in STEM occupations [12], [13]. Overall, women earned 57.34% of all bachelor's degrees in 2016, which means there were 134 women graduating from college that year for every 100 men [14]. However, women make up a disproportionately low share of degree holders in all STEM fields, particularly engineering [15]. About 20% of undergraduate engineering degrees are awarded to women, yet only 13% of the engineering workforce are female [16].

The metaphor of the "leaky pipeline" [17] has been used to describe the progressive loss of women on the career ladder. The phenomenon is clearly visible in the higher education sector with female engineers accounting for 20% of engineering graduates but only 6% of professors in engineering and technology [18] are female. The leaky pipeline starts early. From middle school

through college, female students perform worse on some types of science and mathematics tests compared to male peers and report less confidence and aspiration [19]. Gender gaps in science and math performance have been closing; however, there is a large gap when it comes to women aspiring to be in STEM fields [20]. Even when females perform as well as their male peers on STEM tests or better, many lose interest and do not pursue advanced courses, majors, and careers in STEM. There is an exodus of talented females who could otherwise become the next generation of scientists, engineers, and creators of technology [21]. This research explores the factors underlying the underrepresentation of women in engineering and suggests remedial measures as a necessary preamble to increasing women's recruitment and retention in engineering.

Reclaiming History

The National Council of Women was created in the United Kingdom during the 1914-18 war to get women into workforce so that men can join the armed forces. A subcommittee of this organization formed Women's Engineering Society (WES) on 23 June 1919. This group of influential women had government backing to support women engineers who were welcomed into the profession during World War 1. Nevertheless, at the end of the war, these women were forced to leave the workforce to release jobs for men returning after the war. These women founded WES, not only to resist this pressure, but also to promote engineering as a rewarding job for women as well as men [22]. It was a welcome change to see the engineering world open its doors to women, who had until then, felt that engineering was not an area of work that was appropriate for them [22]. In 1919, the tremendous work performed by women during war was universally acknowledged. Further, given women's systematic participation in the labor market, and their ability to adapt to the changing economic environment, it was illogical that they would be hindered from giving their willing and effective assistance in many other industries [23]. According to [24], the following resolution was passed establishing the educational and economic rights of women at the Women's International Congress:

> "All opportunities of education, general, professional, and technical, should be open to both sexes. Women should have the same opportunity as men for training and for entering industries, professions, civil service, and all administrative functions. Women should receive the same pay as men for the same work. Lastly, the right to work of both married and unmarried women be recognized; that no special regulations for women's work different from regulations for men should be imposed contrary to the wishes of the women themselves."

In the early 20th century, a large proportion of the human population was of the opinion that the right place for women was in their homes, and that their duties should be entirely domestic. The mistake comes in when this opinion is generalized to state that, because it was true for some, it must necessarily be true for all [25]. Even though engineering industry's doors were closed to women in 1919, they were opened again by persistent effort with the restoration of Pre-War Practices Act [26]. In the 1960s, only less than 1% of practicing professional engineers were women [27]. Women engineers were a minority throughout the world, and it was only by getting together on occasions such as conferences and meetings, that they made themselves heard and seen [28]. Women of all nations, given the right education and social climate, could equal men in intellectual achievement [28].

Looking at the workforce statistics from 1977, women participation in engineering professions was less than 1%; 2% in accounting; 5% in architecture; 15% in dentistry; 10% in

veterinary surgery; and 14% as general practitioners. Based on these statistics, WES decided to discover how its own members were faring by conducting a survey among its members in 1983. The results were summarized in [29] as follows. A majority of the respondents thought that their promotion was a result of their hard work alone. Half of the respondents indicated that their progress might have been easier if they were male, and half of them stated that children were a hindrance to progress.

Female students were largely prevented from pursuing higher education until the 19th century. Before then, female seminaries were the primary alternative for women who wished to earn a higher degree. However, women's rights activists fought for higher education for female students, and college campuses turned out to be fertile ground for gender equality activism [30]. In the early 1900's, at the University of London, all degrees were available to women and they were warmly encouraged to pursue education. Several researchers encouraged female students by motivating them. They believed that women who wish to take up engineering work must not get discouraged by the initial difficulties and the absence of well-defined openings and that opportunities will emerge in time [31]. Starting in 1979, more women have been enrolled in higher education than men in the United States. However, this proportion is not reflected in the field of engineering.

On June 19, 1964, the United States passed Title VII of the Civil Rights Act of 1964 prohibiting employment discrimination based on sex, race, color, religion, and national origin. This act made it possible for an increase in the number of women in the engineering field. Another important milestone was the passing of Title IX of the Education Amendments of 1972 that states that no person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance. The number of women in many other professions previously dominated by men, including law, business, medicine and some STEM fields have increased; however, the representation of women in engineering did not enjoy the same rate of change [32]. Women represent only 13% of engineers and earn only 90 cents for every dollar their male counterparts make. This gender disparity is discouraging female students from considering engineering as a major or choosing engineering as a career.

Barriers/Retention Challenges

According to Bandura's self-efficacy theory [33], a person's belief about his/her ability to successfully perform a task may be an important factor in the choice of certain behaviors or activities. Wigfield and Eccles [34] built upon Bandura's theory by arguing that in addition to self-efficacy, an individual's choice of activities and behaviors will depend not only on how well the individual believes that he/she will do on a given task, but will depend also on the value that the individual places on the activity or behavior. According to this theory, expectancy and value directly influence achievement choices. If an individual expects to do well at a given task/goal and has placed a value on succeeding at that task/goal, then he/she will work to accomplish the task/goal. These observations very well relate to women in engineering as women sometimes think that they are not capable of working on technical jobs and so shy away from choosing engineering careers [35].

Perceptions of career barriers are based on individuals' beliefs about environmental or interpersonal conditions that can inhibit career development and advancement [36]. There are many obstacles that prevent women from pursuing a career in engineering [37]. The gender gap in

education and employment in STEM fields is significant for three reasons. First, scientific and technological knowledge is becoming increasingly crucial to active citizenship, for engaging in issues ranging from climate change to new reproductive technologies. Second, STEM fields have value and power in society and so, patterns of differing participation in them are ways in which inequalities are reproduced. Third, given the significant national and international investment in science and technology, both in terms of financial resources and of our hopes for 'progress', having a diversity of people, with a variety of experiences, working in these fields is crucial. Thus, removal of barriers is addressing social justice in the fields of STEM, and contribute to increased participation of women and minorities.

Recent studies [38] in countries like India suggest more and more females participating in the growing technology sector in India. One of the reasons cited for more female participation in technology is that in-college environmental barriers for female engineers do not exist in India as they do in the United States. There were very few evidences that any in-college environmental barriers linked to gender existed and there was no evidence for existence of a "leaky pipeline" for females in the engineering education and career path. In the study [38], females in both engineering and non-engineering disciplines consistently reported to be more confident, open to working with males and respected as compared to male students. In fact, the **female engineering students came out to be the most confident among all the groups.** Identifying the strategies that worked to increase female participation in engineering will assist us in understanding the reasons for higher percentage of women in engineering in countries like India.

There may be many factors contributing to the discrepancy of women in STEM jobs, including: lack of awareness about possible careers, lack of female role models, gender stereotyping, and less family-friendly flexibility in the STEM fields. Regardless of the causes, the findings of this research provide evidence of a need to encourage and support women in STEM [10]. While the climate for women in engineering has improved in recent years, misconceptions about engineering, lack of encouragement, peer pressure and other factors still remain as barriers preventing more women to pursue a career in this non-traditional field [39]. From a 2016-2017 statistic observed by the Society of Women Engineers (SWE), 30% of women who left engineering profession cite organizational climate as the reason for quitting [40] (see Table 1 for more details).

Table- 1 Statistical report from SWE [40]

Over 32%	Switch out of STEM degree programs in college
30%	Women who earned a bachelor's degree in engineering are still working in engineering 20 years later
30%	Women who left engineering profession citing organizational climate as the reason.

Organizations seeking to retain, and advance women engineers may find it of value to provide mentors and sponsors to aid women in the workplace. Literature shows that women who have support from their supervisors/managers are more engaged at work [41]. Another obstacle known as the "leaky pipe syndrome" [38], occurs when female students are diverted from math and science courses early in high school where pre-university career choices are made [42]. It has been argued that this behavior is associated with issues of competition, isolation, lack of female role models and not due to lack of academic ability. Systemic obstacles include cultural influences, gender stereotyping at home and in school, peer pressure, and images in the media [38]. Many

youths do not have a clear idea of what engineering is or what engineers do. The same is also true with many parents who cannot provide guidance to their children (especially young girls) or pique their interest about career choices in engineering. Often the female students assumed that engineering was too complex and difficult for them. The perception of difficulty is an obstacle that discourages female students from pursuing engineering as a career, thus pushing them to careers that society perceives as achievable. On the contrary, encouraged by parents and peers, boys engage in mechanically oriented hobbies, which prepare them better for the practical aspects of engineering [38]. According to [38],

> "Engineering is perceived as a technical, often a solitary pursuit, in which one works with machines rather than people. Career options in engineering are not well known by most adults, let alone teenagers, and are not well represented in high school curricula or through career guidance counseling. This affects girls disproportionately, as they typically have less access to information about engineering outside the school environment."

Teacher stereotypes result in teachers encouraging male students to choose STEM subjects more than female students, and this attitude impacts female student' choices. [43, 44]. In contrast, teachers supporting female students encourage further progress in STEM [45]. Research documents that female and non-white students perceived significantly more career barriers than men [46]. Women serving as role models might provide a more balanced view of the field and help in forming a realistic perception for students about engineering and careers in the field.

Impact of Role Models and Perception of Female Students

Studies were conducted to determine the impact of female role models' visits to high schools and integrated science classes where female students were enrolled. The visits by female role models raised awareness about career options and possibilities for female students. At that age, projecting themselves into a long-term career path may be very difficult for students. It may be that female students need long term mentoring by female role models [47; 48]. A student's determination is influenced by the role models with whom they relate. Women students who read biographies of women engineers and strongly identify with these role models are more likely to pursue engineering careers, than women who do not identify with them as strongly [49]. Thus, utility of role models is very germane.

Access to role models and mentors influences successful professional development. Young adults identify with successful female role models whose presence allows them to think: "If she can be successful, so can I" and "I want to be like her." Typically, however, female college students encounter few same-sex role models who are faculty in STEM departments. STEM faculty members (especially full professors in physical sciences and engineering) are four times more likely to be men than women [50]. However, when STEM professors are female, their presence in classrooms has clear benefits for female students. For example, one study found female students enrolled in college courses in calculus taught by female faculty (compared with male faculty) felt more confident about their math ability and viewed mathematics as central to their sense of self, which in turn increased their intentions to pursue STEM careers [49;51]. Role models also serve as mentors who guide professional development, champion students' work, and broaden their professional network. A dearth of role models means undergraduate women are less likely to learn how to navigate the path from their first year in college to engineering careers, which involves the development of social capital necessary to persist in an engineering job.

Awareness about What is Engineering and What Engineers do

In order to increase awareness about the field of engineering to female students, it may be important to start with middle school students and continue the efforts in high school. This would lead to sustained interest in the subject, improved recruitment percentages and increased retention rates in engineering colleges. In middle and high school, mothers' (more than fathers') support predicts adolescent girls' motivation to persist in science and math [52]. On the downside, on average, mothers apply gender stereotypes about math and science to their children more than fathers do [53]. These studies have led the authors to hypothesize, that an early awareness about what is engineering and what engineers do, must be imparted to the middle and high school female students and their parents. This knowledge is likely to bring about positive change in their perceptions of the field. Another hypothesis is that having a positive attitude toward the field of engineering would help in increasing recruiting and retaining female students. It would also be interesting to see to what extent positive parental attitude toward engineering could be attributed to the students' attitude toward the field. British Gas did a survey and [54] stated the following:

> "The research involved over 2,000 young people aged between 15 and 22. It found that women are turning their back on these sectors for a variety of reasons, including a lack of science, technology, engineering and mathematics knowledge (30%), a perception that the industries are sexist (13%), and a belief that science, technology, engineering and mathematics-based careers are better suited to men (nine percent)".

High School Context and Formation of Educational and Career Plans

Schools could play a positive role in highlighting the salience of gender in career relevant decisions including the gender gap in science, technology, engineering, and mathematics orientations [55]. A strong high school curriculum in math and science provides more opportunities for concrete experiences and competence and provides a partial antidote to gender stereotyping and the discouragement of female students' interest in STEM fields. Accordingly, the professional orientation of such high schools and the experiential knowledge inherent in a strong STEM curriculum may lead to a reduced gender gap in STEM orientation during high school.

In addition, students find STEM courses more meaningful when they connect classroom experiences with personal goals. Academic tasks that are personally relevant enhance motivation, attention, learning, and task identification [56, 57]. For example, when students learn math via hands-on projects, rather than abstract instruction, they view the subject as more interesting and personally meaningful [58]. Importantly, female students are more interested in math instruction taught from an applied perspective than male students [59, 60]. STEM fields are (mis)perceived to impede communal goals whereas service professions (social work, nursing, teaching, human resource) are perceived to facilitate communal goals [61]. Because communal goals interest females more than males [62], the seeming lack of it between these goals and STEM stereotypes make female students move away from STEM careers. Stereotypes about STEM are clearly inaccurate: physical and life sciences, engineering, and technology involve intense collaboration within teams and are critical to solving real-world problems that help people and society. However, female students in middle and high school levels are unaware of communal values inherent in STEM occupations.

Recent research on gender differences in math ability shows that the gap in math performance and course taking has largely closed [63, 64]. Not only is female students'

performance on math tests very similar to that of male students, female students take at least as many math classes in high school as do their male counterparts with a similar level of class rigor [65]. Different characteristics of classroom teaching show substantial effects on students' academic self-concept and their interest in a subject [66]. Comparisons in the classroom set an external frame of reference for the self-assessment and attribution of achievements [67]. Teachers' support in the attribution of achievements can help students overcome gender-specific attribution patterns [68, 69]. Teacher behavior can support students' interest and their development of a positive academic self-concept and encourage students to perhaps even experience STEM as their favorite field, all while keeping in mind that opposite effects are possible as well [70].

Workplace Environment

Occupational turnover is costly, especially in fields like engineering that are characterized by rigorous education and training requirements [67]. Despite increased efforts from researchers, there are still large gaps in our understanding of the reasons for why women leave engineering. Women who go to college intending to become engineers stay in the major less often than men [16]. Most women who left engineering stated that it was difficult for them to find part-time jobs in the engineering field, and that was the main reason they left the occupation altogether. Some women reported that their supervisors did not support them when they needed maternity leave or requested more flexible work schedules [71]. A recent survey by SWE also reported that only 30% of women who graduated with a degree in engineering are still working in engineering field, after 20 years [72].

The under-representation of women in engineering creates an environment where women are the minority and often do not get the support they need from their managers or colleagues [41]. There are numerous explanations that are offered for this discrepancy, including a lack of mentorship for women in the field; reasons that lower self-confidence amongst female engineers; and the demands of maintaining a work-life balance. According to [73, 74] the top reasons women elect not to work in STEM related jobs are:

- Faced discrimination in recruitment, hiring, promotion (39%)
- Not encouraged to pursue science, technology, engineering, mathematics from an early age (39%)
- More difficult to balance work/family in science, technology, engineering, and mathematics jobs (33%)

On the other hand, there are more women in technical fields including in engineering and research reveals that women in India are exposed to images of other women in technology industry through media including brochures, public billboards and other advertisements

Proposed Recruitment Strategies

Despite efforts being made to increase the number of females working in STEM fields according to the Congressional Joint Economic Committee, only 14% of all professionals working in the engineering industry are women. This number is drastically lower than the percentage of women who are part of the entire U.S. labor force [75]. The Department of Labor reported (Table-2) women made up 56% of the country's workforce as of December 2019.

Table 2. Labor Force Status of Women and Men [76]

EMPLOYMENT-POPULATION RATIOS[1]

Group	3-yr History	Ratio	Δ1 mo[2]	Δ1 yr[2]
Total		61.0%	0.0%	+0.4%
Women		55.7%	+0.2%	+0.5%
Men		66.8%	0.0%	+0.5%

Research conducted by the National Science Foundation (NSF) documents that the percentage of female science and engineering workers continues to be lowest in engineering, where women constituted 14.5% of the workforce in 2015 [77]. Among engineering occupations with large numbers of workers, women accounted for only 9% of the workforce of mechanical engineers and about 10% to 13% of the workforce that included electrical and computer hardware engineers, aerospace, aeronautical, and astronautical engineers. During the past two decades, the proportion of women increased among workers in engineering (from 9% to 15%). This increase was led by an expansion of women's numbers in the workforce (by 108% in engineering), while men's numbers barely changed between 1993 and 2015 [78].

This background motivated the authors to investigate the participation of women in engineering and try to answer the following questions:

- What are the main reasons women are interested in engineering?
- What are some barriers to women developing an interest in engineering?
- How can more young women be encouraged to develop an interest in engineering before enrolling in college?
- What are the issues that are critical to recruitment and retention of women in engineering and how to develop strategies to overcome them?

Survey Analysis

To answer these questions, a survey (Appendix A) was designed and administered to undergraduate engineering students (both male and female) at the university where the authors are employed. Purposive sampling was utilized to collect information on why students were interested in engineering and the barriers the students and their friends encountered. Out of the 86 students who took the survey, 57 were male and 29 were female. Figs 1-3 show the gender mix, ethnicity and year in college of the students who took the survey.

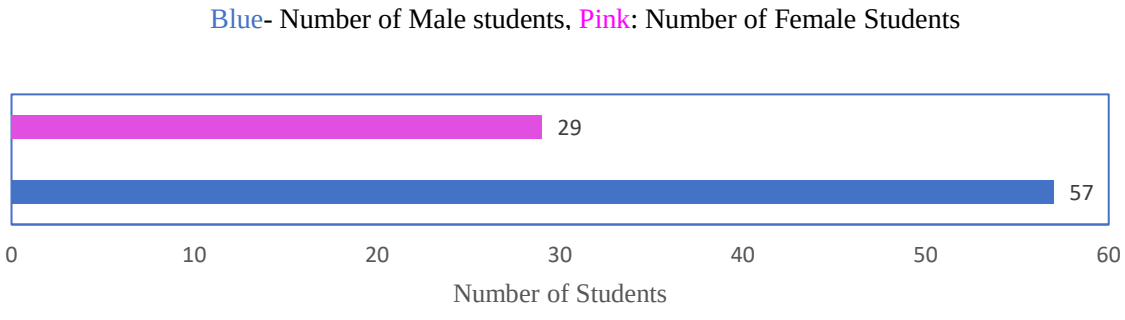

Fig. 1. Gender of students who took the survey

Red: Asian or Asian American Blue: Hispanic or Latino Green: African American Orange: Caucasian

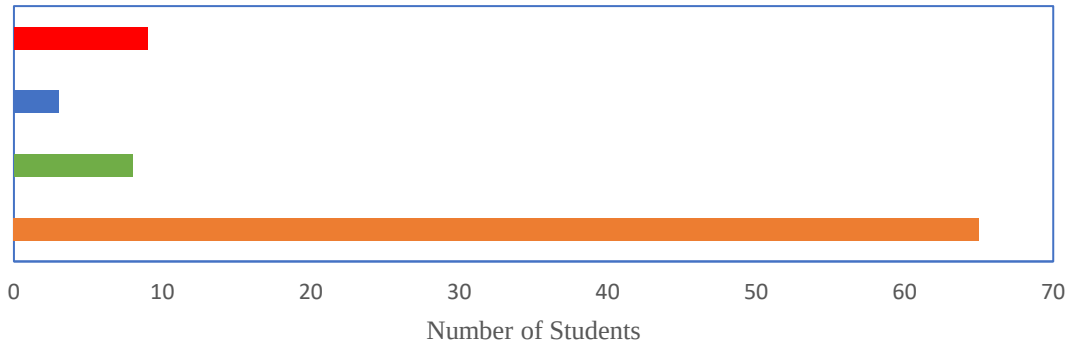

Fig. 2. Ethnicity of students who took the survey

Red: Freshmen Green: Sophomore Purple: Junior Blue: Senior

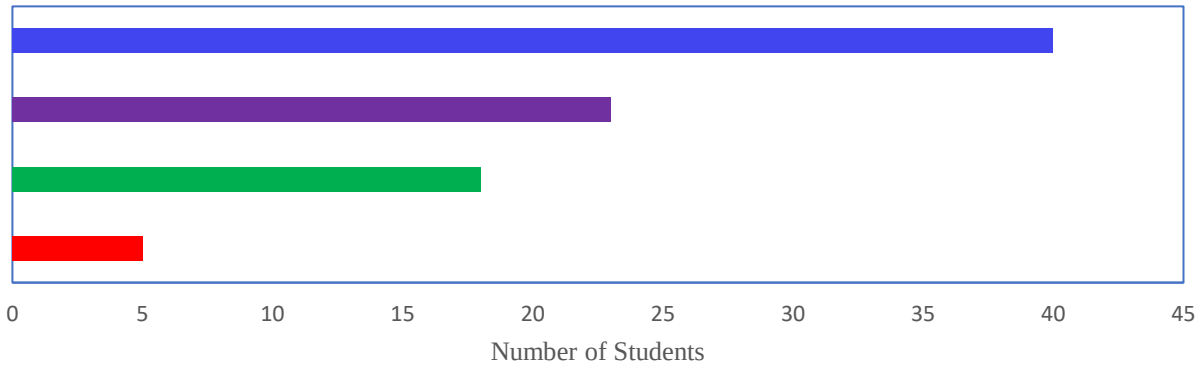

Fig. 3. Students' year in College

As seen in Fig. 4, when asked about the person *who* has influenced them to choose engineering as their field of study, more than 50% of the students answered that they were motivated on their own due to their interest and career research they conducted themselves. However, 29% of the students indicated that they chose engineering due to encouragement/career advice provided by their parents which highlights the major role parents play in guiding their children toward their future careers. Table-3 shows the gender wise distribution of responses to the question "Who influenced you to choose engineering?"

Table-3 Distribution of results based on gender for the survey question "Who influenced you to choose engineering "?

Answer	Male students (%)	Female Students (%)
Parents	12	17
Teacher	5	9
Guest speaker	1	0
Guidance counselor	1	2
Others	19	34

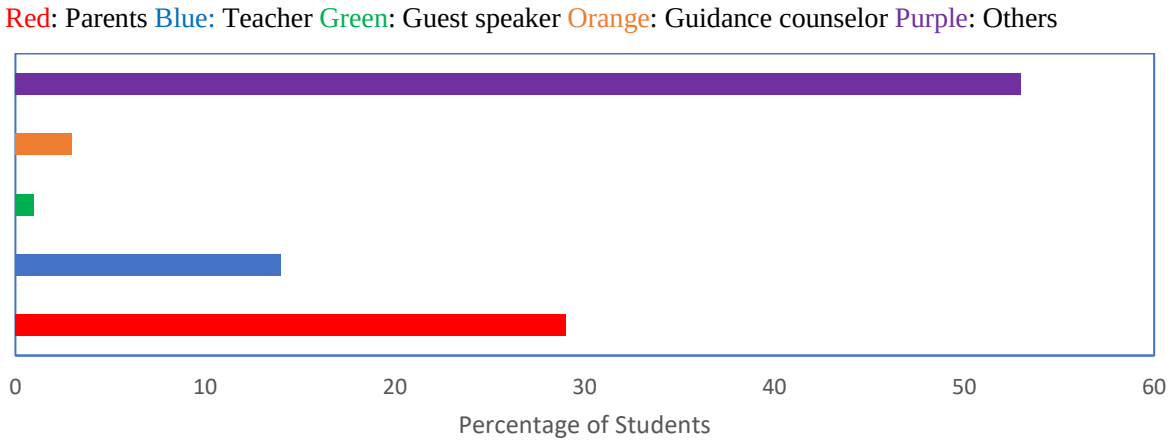

Fig. 4. Students' response to "Who influenced you to choose engineering "?

Another crucial aspect is *when* (at what grade in school) female students decide their career path. As data in Fig. 5 show, the majority of the students made that career decision either in middle school or high school and only 20% waited until college to make that choice. The survey confirmed the authors' belief that reaching out to female students while they are still in middle and high school and educating them about careers in engineering helps them consider this field and see themselves as future engineers. Table-3 shows the gender wise distribution of responses to the question "When did you decide to choose engineering as a career?"

Table- 4 Distribution of results based on gender for the survey question "When did you decide to choose engineering as a career?"

Answer	Male students	Female Students
Middle school	10	4
High school	17	19
College	12	8
Others	9	6

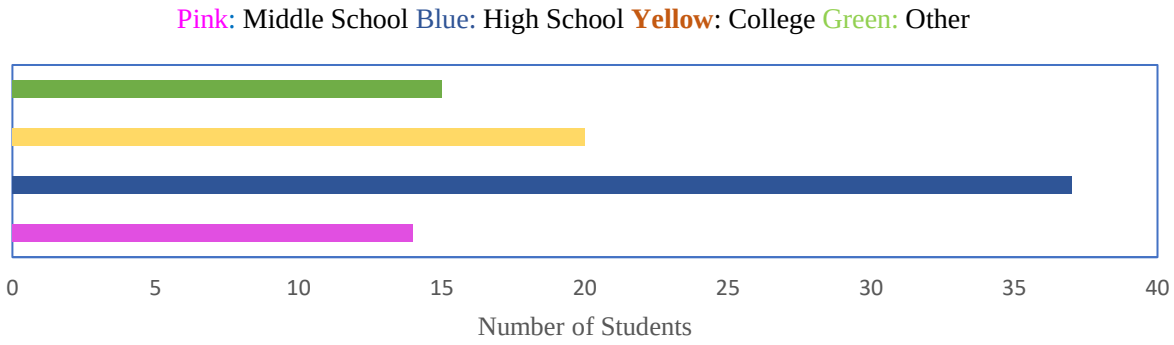

Fig. 5. Students' response to "When did you decide to choose engineering as a career?"

Aside from career stereotypes, another key barrier is the negative perception about the difficulty of engineering subjects. Despite past findings showing that female students, teachers, and parents are usually aware of the importance of engineering, established perceptions about the difficulty of such subjects at high school level is ultimately inhibiting women from entering the sector.

When asked about the barriers they faced while choosing engineering as their field of study, nearly half the students listed self-doubt about their abilities and anxiety about the rigor/difficulty of the courses they need to take in the major. Female students link engineering to problem solving, analytical thinking, innovative, creative thinking, decision making, and teamwork. Not surprisingly, the top reason listed (75% of respondents) for their friends not choosing engineering as their field of study was their lack of confidence in their abilities, especially in courses requiring advanced knowledge of mathematics. Past research shows that for female students, the key drivers of subject choice are how good they are at the subject (94%), the subject syllabus (92%) and whether the subject teacher is knowledgeable (91%) while 87% believe whether the subject teacher is fun is also important.

Some respondents mentioned that the female students were intimidated by the sheer number of men taking engineering courses and presumed that "it is not for them." There is a stigma associated with women choosing engineering that they will have to struggle in their career since the jobs are mostly taken up by their male counterparts. This fear about their job and career prospects forms a major hurdle for female students thinking about choosing engineering as their field of study. Parents and teachers are the biggest influencers of school subjects chosen amongst female students and also are most likely to influence career aspirations. Parents continue to struggle to make informed decisions and give guidance to their daughter.

When asked about the reason for choosing engineering (Fig. 6), 62 students said that they were interested because they were good in Math and Science, 49 listed high salaries and career opportunities, 21 listed influence by someone employed in the engineering, and 24 mentioned encouragement by parents as a reason for choosing engineering. " What made you interested in Engineering?"

Table-5 Percentage distribution of gender wise responses to the question " What made you interested in Engineering?"

Answer	**Male students (%)**	**Female Students (%)**
Someone I know was in the field	9.06	3.08
Career opportunities	17.14	11.18
A relative was an engineer	7.24	4.32
Other	8.42	3.72
Good at math and science	25.34	10.5

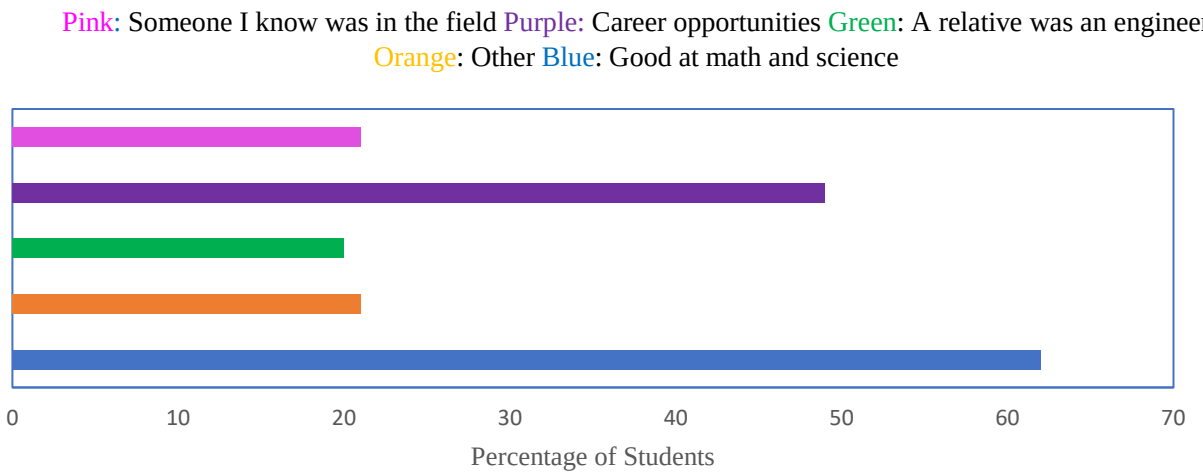

Fig. 6. Students' responses to" What made you interested in Engineering?"

The present youth population have little or no real understanding or perception of what engineering is. Their understanding lacks clarity with regard to the field of engineering and trade school occupations such as a mechanic or repairman. Many people understand an 'engineer' to be someone who does manual work, probably with machinery. This misleading 'grease behind your fingernails' image can discourage pupils, especially female students, and promotes an image which does not accurately reflect a profession that has changed radically over the last 20 years [38]. High school students, including females, and the people who influence them—teachers, school counselors, parents, peers, and the media—largely do not understand what a career in engineering looks like and therefore don't consider it as a career option. Undeniably, misconceptions regarding exactly what engineering is about, constitutes a real barrier to understanding the profession.

It is observed from the survey, that the major factors which contribute to this under-representation include inadequate curriculum content and delivery, biased teaching materials, lack of role models, lack of understanding of what engineering is and what engineers do in their career, and negative socio-cultural attitudes and practices. To address these shortcomings, the authors of this research article propose to develop specific strategies to attract and retain women in engineering. The approaches/methodologies used in these strategies will be formulated as a series of activities and events designed to encourage female students in middle/high schools to understand what engineering is and what an engineer's typical work day looks like, break the illusion of engineering being a "man's field", educate the parents on how they can encourage their female children to be passionate about engineering and build some engineering activities/experiments to motivate female students to choose engineering as their field of study. Though the latest nationwide survey by SWE shows that the there is a 40% increase in total bachelor's degree s awarded in engineering and computer science, only 17% of tenured/tenure track faculty in engineering are women [79].

Conclusion: What can be (and should be) done?

The primary goal of this research paper is to identify reasons for women underrepresentation in engineering and to propose methods to attract and retain women in engineering. In the first part, the authors focused on the importance of engineering and how gender parity and other factors have played a significant role in the number of women in engineering and

about the leaky pipeline problem in the past. The latter part dealt with assessment of the views of male and female students on reasons why they chose engineering at college and about the barriers they faced, if any in the present. The survey results support the conclusion that young women do not shun engineering careers just because of laziness or inability- they simply do not see it as attractive enough compared to other options due to ignorance and a host of psychological and financial signals sent by the society and business worlds. This study has only scratched the surface in the purview of the subject of female underrepresentation in engineering. However, it illustrates an interesting phenomenon, which could be one of the major contributing factors to the leaky pipeline problem. Combination of negative stereotypical perception about engineering and an apprehension about enrolling in mathematics-based courses may be contributing to the current state of "leaky pipeline problem." In order for all the efforts to attract and retain women in engineering to be successful, both the perception and apprehension should be challenged and eventually changed. Because stereotypes are embedded in us: in our families, in our beliefs, in our culture, in our media, and in our society at large; they are extremely slow and reluctant to change. However, the war against stereotypes should start, and it should start from all the stakeholders. In future, the change should be initiated and achieved in a consistent and targeted manner, supported by sufficient resources and by practical policies. Engineering educators need to increase public awareness by addressing deep rooted misconceptions about the field of engineering while emphasizing the importance of the field of engineering through public forums. Further, it would be of value to understand what contributes to larger number of women engineering students and professionals in **other nations, and focus on** recruiting and retaining women in the field of engineering may be worth replicating in educational institutions (high schools and Universities). **Parents, specifically fathers in these nations encourage girl children to enter the field of engineering.** If the role of Engineers is more visible and better understood, more young people (both females and males) would be attracted to engineering as a career. Therefore, the time for action is now!

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Appendix A

Survey Questionnaire for the Project
"Attracting and Inspiring Middle School and High School Girls to Choose Engineering as their Major in College"

1. What is your gender?
   Female
   Male
   Transgender

2. Which race/ethnicity best describes you? (Please choose only one.)
   White or Caucasian
   Black or African American
   Hispanic or Latino
   Asian or Asian American
   American Indian or Alaska Native
   Native Hawaiian or other Pacific Islander
   Another race

3a. What is your major?

3b. Which year are you in college?
   Freshman
   Sophomore
   Junior
   Senior

4. Who influenced you to pursue a career in Engineering?
   Parents
   Teacher
   Guest Speaker
   Guidance Counsellor
   Other (please specify)

5. When did you decide to pursue Engineering as your career?
   Middle School
   High School
   College
   Other (please specify)

6. What barriers did you overcome to pursue Engineering?

7. List some reasons why your friends chose NOT to pursue Engineering as a career? (Please specify)

8. What made you interested in Engineering?
   Good at math and science
   Someone I know was in the field
   A relative was an engineer
   Career opportunities
   Other (please specify)

9. In your opinion, suggest a few actions that would encourage more women to pursue Engineering? (Please specify)

10. What do you think are reasons that discourage women from pursuing Engineering?

11. Do you believe that females and males have the same opportunities to pursue Engineering?
   Yes
   No

12. Do you believe that females and males are treated equally in the Engineering field?
   Yes
   No

13. If engineering was NOT an option, what would be your major?