Influences of Female/Women Engineering Professionals at the Workplace, Home, and Community

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Abstract

This paper explores the influence of women engineering professionals at their workplace, home, and community. Participants of the study were members of the Women in Engineering Division (WIED) of the American Society for Engineering Education (ASEE). The study targeted these cohorts because WIED works to increase the participation of women at all levels of engineering education and the profession. An electronic survey was emailed to members of the division via their listserv. Survey data was collected and analyzed. Of the 193 responses received, two-thirds were first generation engineers in their families, 70% were satisfied with their mobility at the work place, and 99% felt they made a positive contribution at work. A large percentage (85%) of participants stated that they influenced activities at their work place compared to community (13%) and home (10%). Remarkably, 46 participants (24%) had daughters who were attending college, of which 25 (54%) were pursuing a degree in engineering. Subsequently, we developed causal loop diagrams (based on a system dynamics/thinking modeling approach) to capture the complexity of the interactions between women engineers, community and the educational aspirations of their college-aged daughters. The causal loop diagrams predict that an increase in the number of women engineering professionals yield an increase in the number of female students enrolling in engineering colleges, creating a feedback loop that gives an exponential growth in the number of women engineering professionals.

1. Introduction

Educate women and their community will prosper. Deny them education and the world will suffer [1-3]. The study sought to find how women in the engineering profession perceived their influence at the workplace, home, and community. According to the 2010 U.S. Census, females comprise of 50.8% of the total population [4]. Further, the U.S. Census Bureau shows that 6% of college graduates are women in STEM fields while men were about 18% [5]. Women in the U.S. filled in 47% of all jobs but only 24% of the STEM jobs [6]. In other words, 76% of the STEM jobs are held by men. In community services, women had a volunteer rate of 27.8% in 2015 compared to men 21.8%. Women volunteered at a higher rate than men and this was true across all age groups, educational levels, and major demographics characteristics (such as race and employment status) [7].

Influence is closely associated with leadership. A capable leader provides guidance at the workplace, home, and/or community [8]. It follows that, those influencing are considered efficient leaders that motivate their colleagues, family or community [9, 10]. Transformative leadership idealizes influence which reflect standards of moral and ethical conduct; it inspires motivation; and it provides for intellectual stimulation [11, 12]. Several theories speak to the notion of governing characteristics in leadership. For this study, we get guidance by one that applies to the head, heart, and hand [13].

Conceptual Framework

Davydov and Dellaert white paper [13] discusses about three logical tactics that contribute to successful influence. These include logical (the Head) which address people in a rational or intellectual way. Arguments and information such as facts and figures are brought forward in the best interest of the organization, the team, or the person; emotional (the Heart) connects the communication or decision to a person's feelings of well-being or sense of belonging. The leader appeals to attitudes, values, a common purpose, ideals, and beliefs through inspiration or enthusiasm; and cooperative (the Hands) involve seeking advice and offering assistance. The leader reinforces the connection that he or she has with others. Collaborating to accomplish a mutually important goal extends a hand to others. French and Raven [14] concur with the information above through their personal power theory of charm and appeal for they view it as the most effective way to build relationships and inspire for attaining common goals. Our assumption is that both Davydov & Dellaert, and French & Raven theories are a framework that explain female engineering professionals influences.

2. Method

The authors wanted to understand how female engineering professionals view their influence at the workplace, home, and community. Members of the WIED of the ASEE were chosen for this study because the division works to increase the participation of women at all levels of engineering education and the profession. All members in the division were invited to participate in the study via their listserv.

An instrument consisting of 14 items was developed by the authors, and was pilot tested for validity and reliability to a small population. Feedback from the pilot exercise helped the authors to review the instrument. It was tested to ensure the questions sought the responses expected. Once piloting and reviews were complete, the WIED listserv was used as a vehicle to send the instrument electronically to participants. The original notice resulted to 131 responses. Two weeks later, a second notice resulted in an additional 62 responses for a total of 193. The size of the WIED in ASEE was not known to the authors.

Data Analysis

Because the sample size is small, there is more chance of finding an explanatory effect if potential explanatory variables are dichotomous. Data was organized to make all levels of each variable dichotomous, if possible. The variables include fields such as first-generation, race, degree, marital status, pay, commensurate, mobility, contribution, outreach, etc.

While for the most part descriptive statistics are used to explain the group examined, in some cases we further look separately at the 2-by-2 contingency tables for all pairs of explanatory variable and response variable. Then we perform the *Fisher Exact Test* to check for significance of the association. The null hypothesis for the tests is that there is no association between the two levels of Engineering Major (No, Yes) and the two levels of the explanatory variable, while the alternative is that there is an association. We examined both the two-tailed p-values that reject in both directions, and a 1-tailed p-value which rejects only in the direction observed. In this study, p-values of less than 0.05 were deemed statistically significant and for our case this was only observed once when studying the 46 female engineering professionals that had daughters in college

3. Findings

Findings are presented mostly in descriptive statistics; however, the first generation and the highly paid participant have additional analysis because the two had lowest 1-tailed p-values of 0.149 and 0.107 in this study. The additional analysis for the two is presented in section 3.5.

3.1 Demographics

The composition of respondents indicated that the majority were first generation engineers from their families as shown in figure 3.1.

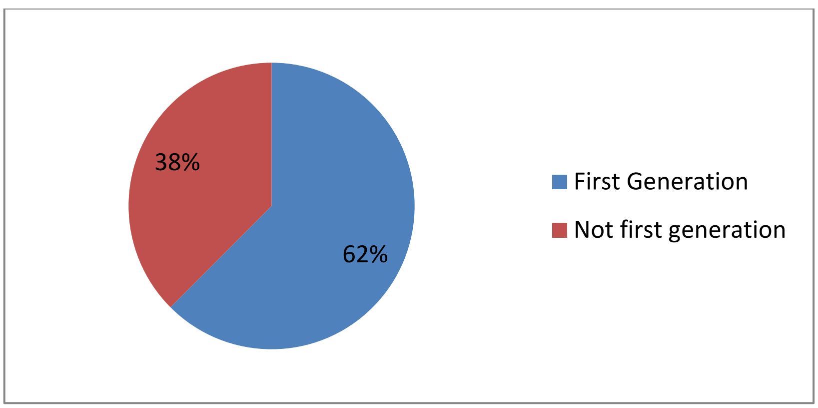

Figure 3.1: WIED – Women engineering professionals' access status

First generation in engineering in their families indicates the resilience they had to exercise to realize their achievements. Inhibitions and minimal success for first generation groups is well documented [15, 16].

Further, the respondents were comprised of 82.5% White, 6.8% Asian, 4.8% African American or Black, 2.7% for Biracial and Hispanics each, and 0.5% Native Americans. In addition, participant marital status indicated that 78% were married, 17% were single, and 5% were divorced.

3.2 Education and employment

The most popular terminal degree was Mechanical Engineering as shown in figure 3.2. Popular majors under ‘other’ were materials, education, computer science, environmental, and aerospace.

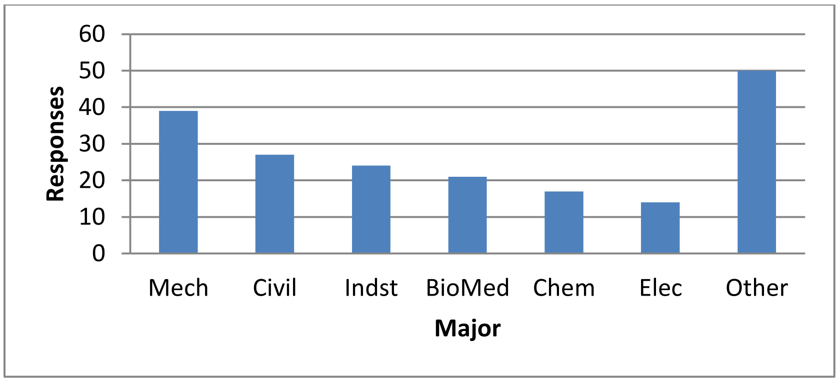

Figure 3.2: Terminal degree of participants

Salaries for the participants are portrayed in figure 3.3, indicating that about 49% had an annual income of over $100,000.

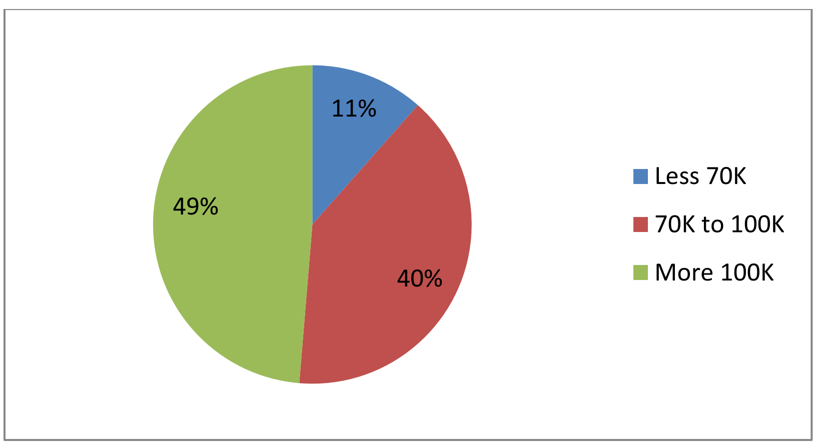

Figure 3.3: Income information of participants

3.3 Employment Satisfaction

In seeking to understand employment satisfaction, four questions were asked. The first was about whether compensation was commensurate with their backgrounds and preparation, the response was mostly positive as shown in figure 3.4. Further 85% said their income was sufficient for their life style, where 15% said not.

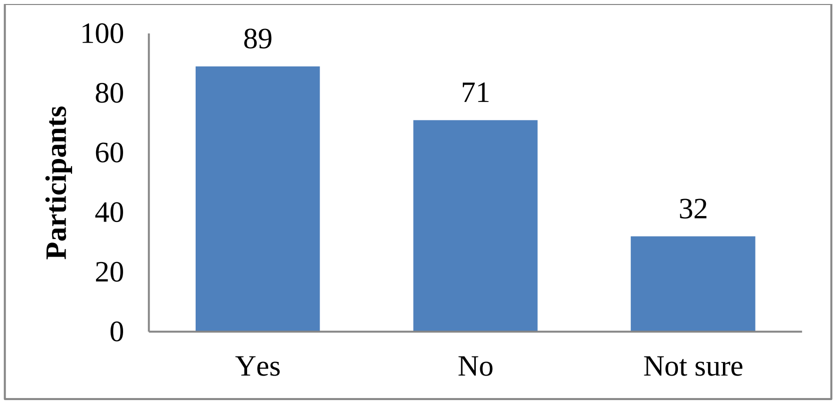

Figure 3.4: Salary satisfaction

In workplace mobility and satisfaction, 70% indicated they were satisfied with their positions, while 30% were not. 99% believed they made positive contributions to their workplace.

3.4 Influence at the workplace, home, and community

Authors found that participants felt that their educational background helped them make significant contributions at the workplace (82%), community (11%), and at home (7%). The participants showed a strong involvement in community engineering related programs as evidenced in figure 3.5.

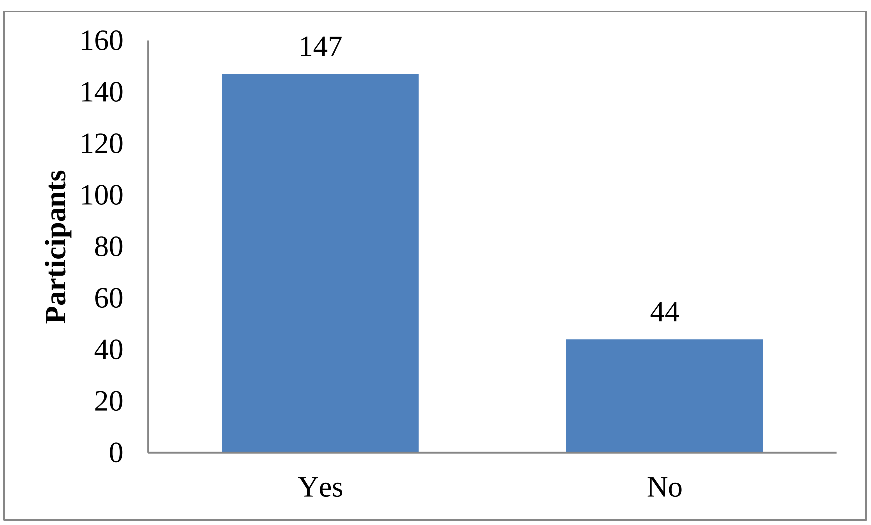

Figure 3.5: Participation in engineering-related outreach activities.

3.5 Information about daughters

Authors sought to find out whether participants had daughters and if they followed similar education experiences as their mothers. Forty-six female engineering professionals indicated they had at least one daughter in college. Twenty-five daughters pursued an engineering degree while twenty-one did not.

A contingency table for first generation and daughters pursuing engineering major was developed to further understand the results.

Table 1. Contingency table for first generation and daughters majors

		Engineering Major			
		No	Yes	Total	Odd Ratio = 2.375
First Generation	No	9	6	15	1-Tail P-value = 0.149
	Yes	12	19	31	2-Tail p- Value = 0.217
	Total	21	25	46	

Table 1 gives the contingency table and Fisher test results for first generation and the engineering major. For Fisher test, the null hypothesis is that there is no association between engineering major and first generation. ‘No association’ is equivalent to saying that the odds ratio is equal to 1.00. If there is an association, that occurs either because odd-ratio is significantly less than 1 or because it is significantly greater than 1. The p-value (0.217) calculated for the two-tail test does not provide any evidence against the assumption of independence. Although a p-value of 0.149 implies a positive association, (61% of first generation mothers have engineering daughters to only 39% of non- first generation mothers),we cannot confidently claim any difference in preference for a daughter being an engineer between the two levels of first generation. Additional investigation about the first generation group indicated they were mostly white and married.

‘Highly paid’, defined as annual earnings of $100K or more, was an insignificant indicator on whether their daughter was to pursue an engineering degree or not. 67% of the ‘Regular-paid’ mothers pursued an engineering degree compared to 44% of the highly paid mothers. The difference is not enough to yield statistical significance at the 0.05 level, as shown in table 2.

Table 2. Contingency table for highly paid and daughters majors

		Engineering Major			
		No	Yes	Total	Odd Ratio = 0.393
First Generation	No	7	14	21	1-Tail P-value = 0.107
	Yes	14	11	25	2-Tail p- Value = 0.149
	Total	21	25	46	

We found P-value = 0.149, which means that there is no significant evidence that being highly paid or not is related to daughter pursuing engineering major. Since the estimated odds ratio is 0.393, we can also test whether the odds ratio is less than 1. We use one-tail Fisher exact test, and generated a p-value=0.107, which shows that even if we had hypothesized in advance that an engineering mother being 'highly paid' (i.e. having annual income > $100K) was negatively associated with her daughter being an engineer, the observed difference in Engineering daughters (67% for 'highly paid' mothers vs. 44% for 'regular paid' mothers) is not quite enough to yield statistical significance at the standard level of 0.05.

In general, we can say there is a high likelihood of:

1. If the female engineer is the first generation or she respects her mobility, it is more likely her daughter will pursue engineering major.

2. If the female engineer is 'highly paid' or applies herself mostly in the workplace, her daughter will less likely have engineering major.

3. Although women in engineering felt that their educational background had little influence (7%) at home, more than half of their college-aged daughters (54.3%) were engineering majors. In other words, their daughters were aspiring to be engineers, following the same career path as their mothers. Could there be a subtle but real influence at home that mothers did not recognize? In a future study, authors intend to compare these results to those of other professions.

3.6 System dynamics approach to studying women engineering professionals

The Authors were intrigued by the survey findings and then proceeded to ask the question "what characteristics lead a female individual to pursue a degree in STEM field or engineering in particular?" And "why do women engineers have a high percentage of daughters aspiring to be engineers?" We explored possible answers to the question by using a system dynamics (SD) modeling approach. This modeling approach allows us to capture the complexity of the interactions between women engineers, community and the educational aspirations of female students.

SD is a modeling methodology developed by Jay W. Forrester for investigating the behavior of dynamic complex systems [17-19]. A key characteristic of the SD methodology is causal loop diagrams (CLD). This involves conceptualizing a system based on closed chains of causes and effects [20]. An analysis of the behavior of causal loop diagrams provide an in-depth understanding of a system and its underlying problem [21]. We employ a qualitative set of CLDs to discuss possible interactions that may encourage female students to pursue a degree in engineering. Vensim PLE software was used in constructing the causal loop diagrams. The authors identified the elements in the causal loop diagrams as key and relevant to the study.

The CLDs are presented in Figures 3.6 to 3.9 and their findings are discussed below. The CLDs is composed of elements and arrows (also known as causal links) linking these elements together in a similar manner (see for example Figure 3.6). The sign (either + or -) on each link describe how changes in one element affect another element. For example, in Figure 3.6, the causal link from "female students enrolling in science, technology or mathematics" to "number of women graduates with science, technology or mathematics degree" is positive (that is +) because an increase (or decrease) in the number of female students enrolling in science, technology or mathematics would produce an increase (or decrease) in the number of women graduates with science, technology or mathematics degree.

A negative causal link from "degree of saturation of engineering profession" to "average income for engineers" is negative (that is -, see Figure 3.8) because an increase (or decrease) in the degree of saturation of engineering profession would produce a decrease (or increase) in the average income for engineers. A complete loop with arrows pointing in the same direction is called a feedback loop and is given a positive (that is +) or negative (that is -) sign within a curved arrow (see Figure 3.6).

A feedback loop is called positive or reinforcing loop, if it has zero or an even number of negative causal links. The reinforcing loop in Figure 3.6 reinforces the change in each element with greater change, resulting in an exponential growth in number of women graduates with science, technology or mathematics degree [22]. A female student's educational aspiration is influenced by many interacting factors including the family (both nuclear and modified extended family) group and the community in which they belong. In a different survey, we found that the majority of female engineering students at the University of Georgia, Athens, GA aspired to be engineers because of the influence of at least one member of their immediate family and/or modified extended family. It is important to understand why most female students with at least a family member in the STEM discipline aspires to become an engineer. The number of women in the STEM disciplines and the community are key factors that influence the career goals of a female student.

3.6.1 Women professionals in science, technology or mathematics disciplines

The authors believe that women professionals have a great impact on the educational goals of their daughters. The causal relationship of women professionals in science, technology or mathematics disciplines is shown in Figure 3.6. Female students, who have parents in science, technology or mathematics disciplines, are highly exposed to career options in the STEM field. The exposure raises greater chances of female students to choose a career in a STEM field. A double line that is perpendicular to the arrow at the arrows handle marks a link as involving a delay in CLDs. Delay is a situation where there is a time lag before the response to a change occurs. For example, it takes about 4 years on average for a female student enrolling in a science, technology or mathematics college program to graduate, which is why there is a delay between ‘female students enrolling in science , technology or mathematics’ and ‘number of women graduates with science, technology or mathematics degree’ in Figure 3.6.

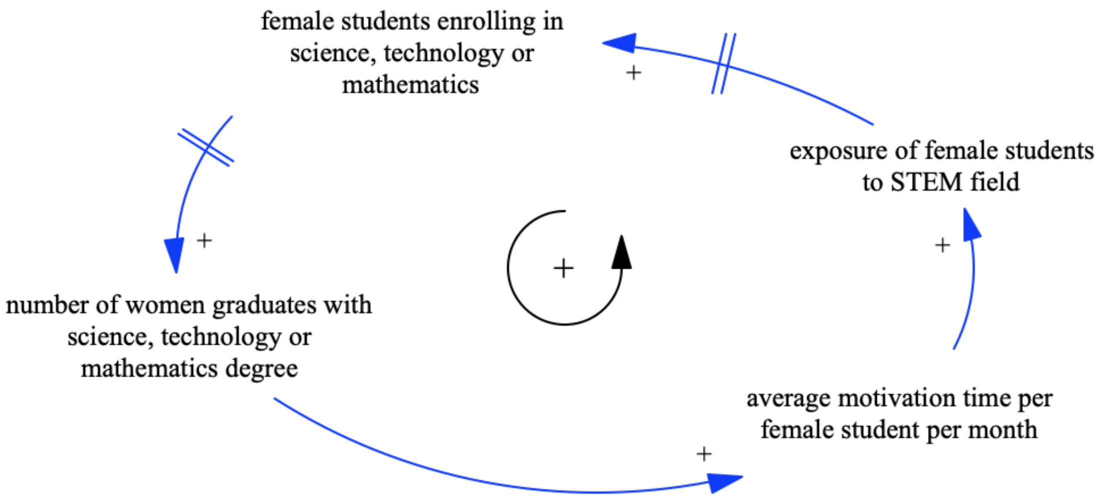

Figure 3.6: Causality for women professionals in science, technology or mathematics disciplines. A positive feedback loop produces a virtuous cycle of events that increases the number of women professionals in science, technology, and mathematics.

3.6.2 Women professionals in engineering disciplines

The authors believe that women in the engineering profession have a greater impact in determining if their daughters will choose a career in engineering. They are able to provide their daughters information on different career options in the engineering profession and also serve as excellent role models for their daughters. The causal relationship of women professionals in engineering disciplines is shown in Figure 3.7. Increasing the number of female engineers increases the total population of engineers. This leads to an increase in the probability of a female student having at least one family member in the engineering profession which in turn increases the exposure of female students to engineering disciplines and consequently the number of female students aspiring to be engineers.

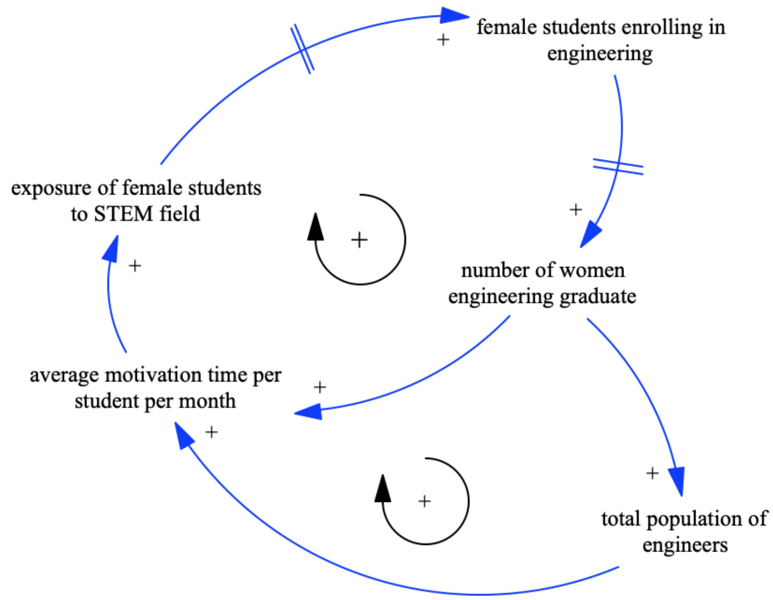

Figure 3.7: Causality for women professionals in engineering disciplines. Two positive feedback loops produce a virtuous cycle of events that increases the number of women professionals in engineering

3.6.3 Community and government interventions

The government is an important force in controlling and guiding public sentiment and behavior. The government equips the community with information and tools necessary to provide awareness of the importance of engineering disciplines to students. The causality for community and government interventions is shown in Figure 3.8.

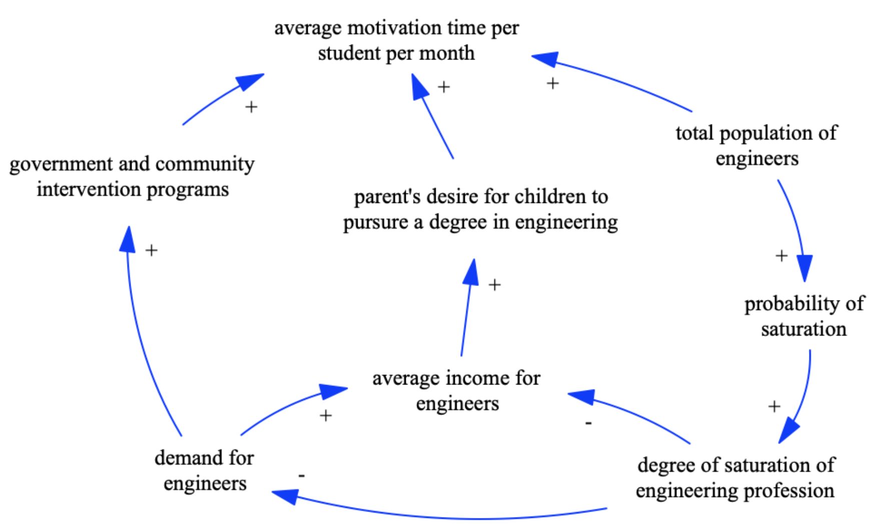

Figure 3.8: Causality of community and government interventions.

Coupling the causality for community and government interventions (Figure 3.8) to the causality for women in STEM discipline (Figures 3.6 and 3.7) yields a complex interaction with 3 positive and 2 negative feedback loops. A feedback loop is called negative or balancing loop, if it comprises of an odd number of negative causal links [22]. A negative (also known as balancing) feedback loop is a self-regulating system. Example, if the current number of women engineering professionals is above the target goal, then the negative loop structures pushes its value down, while if the current level is below the target goal, the negative loop structure pushes its value up (see Figure 3.9).

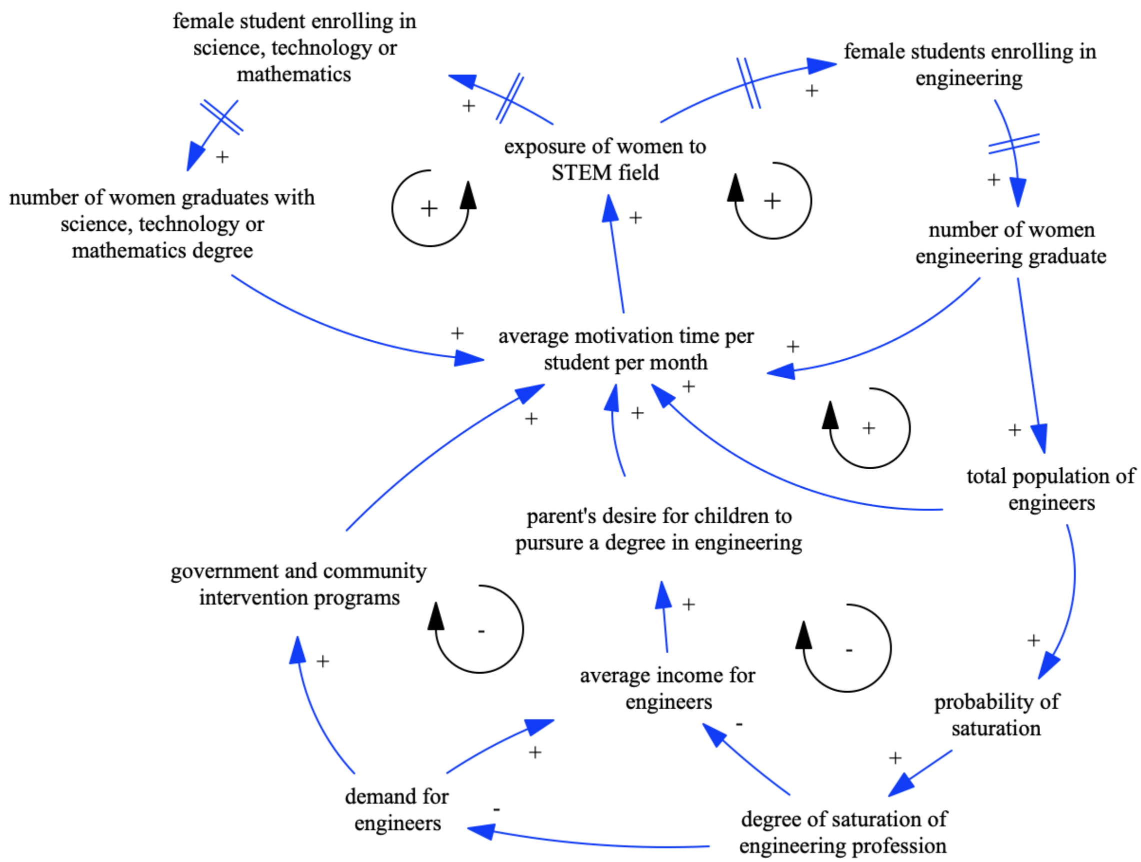

Figure 3.9: Causality model for increasing the number of women professionals in engineering disciplines

In general, the casual loop diagrams show that government and community interventions and degree saturations of engineering profession regulates the enrollment of female students in engineering disciplines. Increasing the number of women in engineering produces a change that leads to a feedback loop that would in turn yield an exponential growth in the number of women in engineering. An interesting feature of the exponential growth is that it is usually slow in the early stages of growth but eventually speed up with time [22]. Thus, the growth in the number of women professional in engineering disciplines would eventually speed up in the future. The community and government has an important role in creating viable programs that highlight the demand for engineering professionals and motivate female students to consider a career in engineering.

4. Discussion and Conclusion

Overall, we found that the female engineering professionals felt that they were more engaged at the workplace, community and home, in that order. Further, some questions emerged from this study, they included (i) to what extent do female engineering professionals have their sons and daughters pursue a STEM (Science, Technology, Engineering, and Mathematics) career; and (ii) what influences the girl child to pursue a major in STEM? Authors have embarked on research to answer these questions and hope that it would generate ideas on where to locate resources to enhance the future STEM workforce.

The study by Adamic and Filiz [23] showed that 'Nurses' daughters are more likely to follow their parents' footsteps; Scientist fathers have scientist daughters at 3.9% above the overall rate; and mothers who work in law are more likely to have sons with legal career. Though this was not the primary aim of our study, we found a similar trend, in that mothers in the engineering profession whose daughters were attending college were more likely pursuing a degree in engineering.

The causal loop diagrams provide vital information that could guide the exploration of policies for increasing the number of female engineering professional. It identifies that government and community interventions and degree saturations of engineering profession regulate the enrollment of female students in engineering disciplines. It also predicts that the number of female engineering professionals would increase exponentially as a result of the feedback loop from their daughters enrolling in engineering programs. However, there is need to encourage female students that don't have close relatives in the engineering profession to enroll in engineering. The lifespan and retirement of women engineering professionals would decrease the pool of women engineering professionals and the number of daughters of female engineers joining the profession is not enough to replenish that pool. This is because only about 54% of college-aged daughters of female engineering professionals enrolled in an engineering college. There is also a time lag of about 18 years after birth before their female daughters would enroll in college. The causal loop diagrams predict that in the short-term, the increase in number of female engineering professionals follow a trend that is consistent with an exponential growth. Quantitative modeling is needed to determine the long-term trend for the increase in the number of female engineering professionals.

A future work would involve the application of a quantitative (i.e. system dynamics simulations, [17]) model for an in-depth study of the influences of female engineering professionals at the workplace, home, and community. The system dynamics model would consist of the elements presented in the CLDs and would incorporate other key parameters such as withdrawal rate of female students from college, retirement rate of women professionals and average life span of female engineering professional. Simulation of the system dynamics model with reasonable parameter values would definitely provide invaluable insight on the long-term trend in numbers of female engineering professionals.

More research is needed to understand why mothers in the engineering profession whose daughters are attending college are more likely pursuing a degree in engineering. This would provide new ideas for implementing intervention programs that would benefit female students that don't have close relatives in the engineering profession.

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