January 2012

Underrepresentation Of Females In Academia: A Relative Rate Index And System Dynamics Model

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A Thesis Submitted to the

Yale University School of Medicine

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Medicine

by

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2012

Abstract

UNDERREPRESENTATION OF FEMALES IN ACADEMIA: A RELATIVE RATE INDEX AND SYSTEM DYNAMICS MODEL. Nupur Garg. Department of Emergency Medicine, Yale University, School of Medicine, New Haven, CT.

Females continue to be significantly outnumbered by their male counterparts in the academic pipeline at the senior ranks. Confounding the problem is the inadequacy of tools used for measurement and analysis of it. A Relative Rate Index (RRI) is a better tool for measuring gender disparities of academic systems than calculating percentages of females in academia. An RRI determines the junctures and scales at which females fall out of the academic track. The RRIs for academic medicine departments at Yale were created using institutional records. Calculations indicate that the fallout for females in academia occurs from assistant to associate professor at a higher rate than associate to full professor in ten of 22 departments, including three that are not evident using only percentage calculations. Thus, RRI is a superior method to percentages in identifying the gender disparities in progression through the academic pipeline.

Integrated and dynamic models enhance the understanding of the system surrounding the advancement of females in academia more so than current linear analyses. Specifically, each factor in the model, when assessed relative to the entire system, gives information that identifies the underlying mechanisms that lead to underrepresentation of females in the academic pipeline. Through content analysis of existing research, working groups, and interviews, a robust model was constructed to illustrate the interdependencies among factors that contribute to females advancing to full professorship in academia. The system dynamics model was subdivided into seven constructs, including *abilities, interests, working environment, work-life, hiring process, sexual discrimination, and economics.* Each construct individually offers valuable insights into the issue of underrepresentation of females in academia and jointly, they lend themselves well towards developing targeted interventions to increase gender equality in academia.

Acknowledgements

I am fortunate to have the opportunity to acknowledge many individuals for their support and dedication towards producing this thesis. First, I am deeply grateful to my thesis advisor, Dr. Lori Post, for her patience, enthusiasm, and dedication towards my achievements. Without her mentoring, this thesis would not have been possible. Also, I would like to acknowledge several other supportive faculty members at Yale, including Dr. Amy Justice, Dr. Hannah Brueckner, Dr. Jo Handelsman, Dr. Marcella Nunez-Smith, Dr. Frances Rosenbluth, Dr. Nancy Angoff, Dr. Meg Urry, Dr. Gail D'Onofrio, Dr, Stephanie Spangler, Dr. Jody Sindelar, Dr. Valerie Horsley, Dr. Federico Vaca, Dr. James Dziura, and Dr. Cynthia Brandt. In addition, Dr. Judi Brown Clarke, from Michigan State University, supported my endeavors throughout. Next, I am deeply indebted to the services and support of my friends, Chris Bolen, Kelly Stanton, Jessie McDonald, ThaiBinh Luong, Brian Coppedge, Rose McCallum, and Michael Pihulic, who provided advice, helpful discussion, and critical reading of the manuscript. Lastly, my family deserves special mention for their everlasting and unconditional love and encouragement, Dr. P. K. Garg, Dr. Anju Garg, Saumya Garg, Neha Garg, and Priya Garg.

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Section 1 Introduction

Underrepresentation of females in upper ranks of academic medicine

Underrepresentation is defined as fewer individuals than would be expected in a given population. The proportion of females in the United States (U.S.) has been roughly 50% since at least 1860.[1] One would expect that if gender disparities did not exist, the distribution of males and females in academia would reflect the distribution of the general population. Despite marked advancement in achievements by females in academic careers, a significant underrepresentation still exists at the upper ranks of academia.[2,3] For example, 47% of U. S. medical students are females and yet only 12% of the full professors in academic medicine are females.[4-7] Forty percent of graduate students in science, technology, engineering, and mathematic (STEM) fields are females and yet females comprise only 26% of STEM full professors.[8] Since STEM fields are generally the feeder undergraduate routes into medicine, it is critical that we begin to examine disparities during this stage. While it is likely that educational disparities and opportunities begin in preschool, this study focuses on the impact of STEM and medical school training as they relate to underrepresentation in the academic ladder track. The ladder track includes professors at the ranks of assistant, associate, and full professorship. The numbers of female graduate students in STEM and the percentage of females in medical school have been steadily increasing and stable at roughly 50%, respectively, for over a decade now (see Figure 1 and Figure 2),[8] however, there is still a gender discrepancy in promotion to the upper ranks of academic ladder faculty (Figure 3).[8] The females who are joining academia from professional and graduate school are not reaching the upper ranks at the same ratio as their male counterparts (see Figure 4)[3] resulting in an underrepresentation of females throughout the ladder faculty of academic medicine and STEM fields.

Why does it matter?

The U.S. has several federal laws in place to ensure that gender discrimination, in fact, does not happen. Title VII of the Civil Rights Act of 1964 prohibits employment discrimination based on sex, Title IX of 1972 prohibits discrimination or exclusion on the basis of sex from any education program or activity receiving federal financial assistance, and lastly the Science and Engineering Equal Opportunities Act of 1980 made "equal opportunity [for males and females] in education, training and employment in scientific and technical fields" the official policy of the U.S.[9,10] Thus, there is legal responsibility for academic institutions to eliminate discriminatory practices based on gender that might be affecting the decisions of females to join academia. "Men and women should have an equal opportunity to serve society, work in rewarding jobs, and earn a living."[10] A greater inclusion of females allows perceptions that are based on the absence of females to be corrected, which in turn leads to decreased gender discrimination. Gender discrimination is often subtle and subconscious in this society and is greatly influenced by images, perceptions, and culture that we are familiar with.[11] Gender discrimination impacts society by furthering gender stereotypes and gender-based discriminatory practices that negatively impact the academic system.[12]

The greater inclusion of females in the scientific workforce has both economic and social impacts. A study focused on gender ratios in working environments concluded that a 1:1 ratio of females to males yields increased innovation, efficiency, and self-confidence in the working environment.[13,14] In other words, gender diversity is critical to improving the overall performance of teams and is optimal at a ratio of 50%.[13] In addition, encouraging females to enroll in medical or graduate schools is an investment for the U.S. economy. The federal government and private sector combined spends about $50,000, not including research and training expenses, per year per person to train a PhD student. It is to the economic advantage of the U.S. to capitalize on this investment and address the issue of why females drop out of the scientific workforce.[10] The U.S.

is also suffering in its global competitiveness. U.S. productivity and innovation is lower compared to other nations with more progressive policies in place for females in the STEM and medical workforce. Other nations are more effective in their abilities to recruit, retain, and promote females through the academic ranks.[12,15] The ability to produce more full rank female academics promotes higher innovation and advancements due to better gender ratios in the workplace. Thus, gender diversity is a major driving force for innovation.[13,14] In order to stay competitive on an international scale, the U.S. must also find a way to make optimal use of its scientific workforce.[10,16] Females are outperforming males in the classrooms of STEM disciplines at the undergraduate level, and yet a lower percentage of females than males choose an academic career in STEM or medicine.[16] Fostering an environment where increased percentage of females choose academia will increases the total academic workforce and its overall diversity, leading to higher scientific productivity and a higher return for the national investment.[16]

Gender diversity in academic medicine has many benefits to society within the U.S. Specifically, a diverse medical workforce leads to increased patient satisfaction.[4] Even more importantly, underrepresented clinicians are needed to help fill the need for health care professionals in the most underserved areas.[4,7] In research, there are benefits to academicians in broadening agendas in setting research priorities, increasing clinical trial participation, and expanding the knowledge base.[12,16,17] Increasing diversity in education and training programs improves the quality of research for practitioners and, hence, subsequent patient care.[12] For instance, for many years, females were excluded from being patients in pharmaceutical trials and clinical studies. This oversight negatively impacted women's health and the societal and economic costs were significant.[18] Finally, inclusion of underrepresented groups in education and training programs improves their quality for all participants.[7] Thus, increasing female representation in academic medicine has a broad range of benefits for academia, the health of society, and the U.S. economy.

How did it happen?

The process of an individual moving from STEM undergraduate studies to a professional or graduate academic position is influenced by several factors. First, individuals must have the intellectual abilities and second an interest to pursue an academic career. These two factors are the composite result of influences from one's background, environment, opportunities, and even each other.[19] For example, individuals who are never exposed to university-based medicine or medical students who lack encouragement to pursue research may never realize that academic medicine is a plausible career to pursue. While it is necessary for individuals to have the right set of skills and interests that alone is not sufficient to prevent the systematic exclusion of recruitment, advancement, and retention of females in academia that is occurring. Policies and practices should be put in place to limit the effects of anything outside of one's ability to be a good academician to determine exclusion. Unfortunately, this is not the case and there is a lack of equal exposure and encouragement to pursue STEM and medical research leading to the gender disparities observed in academia today.

Abilities and Interests

Abilities and interests often predispose individuals to certain career paths. Currently, there is a perceived difference in the abilities and interest level of females and males towards pursuing academic medicine and STEM fields.[15,19] These perceptions stem from the idea that these differences are innate, and therefore, these differences form the basis of the reality as it is observed in society today. Innate abilities are abilities that are perceived as being present from birth and cannot be acquired through learning and practice. Studies show males have an innate advantage with abilities such as verbal analogies, rapid mathematical reasoning, and memory for geometric relationships and manipulation, and females have an innate advantage with abilities such as verbal fluency, rapid mathematical calculation, and memory for the spatial positions of objects.[19] These studies are not only controversial for their methods and assumptions, but when used as a basis for evaluating suitability for STEM proficiency, it is not clear that either set of advantages is more valuable.[15,19] In addition, attempting to value one set of skills over the other overlooks the idea that diversity is important within scientific thinking.

Though innate abilities may play some role in the development of one's skills, humans also have the ability to learn and improve them to a level of mastery through practice.[15,19] This idea has significance for two reasons. First, it brings up the issue of whether innate differences are relevant at all given that all skills can be learned if there is an interest. Second, the belief that skills can be learned also has an impact on performance. When K-12 females believed their capabilities in mathematics could improve with experience and learning, they did better on exams and were more likely to stay in a field utilizing mathematics in the future.[15] In fact, females are now performing better in STEM field classes in undergraduate programs than their male counterparts.[19] Therefore, innate differences in abilities between males and females cannot explain the gender gap observed in academic medicine and STEM fields today. In fact, continuing to attempt to quantify these differences between genders may very well reinforce the biases and practices that lead to the creation of the gender gap as well.[7,19]

If we assume that one's dedication to learning and practicing is more critical to mastery of skills than innate abilities, then it is critical to address the development of one's interest level and the gender discrepancies thereof.[19] The gender gap in interest level for STEM subjects has been decreasing,[19] as is evident through an increase in the number of females choosing STEM majors in college,[15] earning doctorate degrees in medicine and STEM fields (Figure 5),[3,10]and entering careers in medicine and STEM fields (Figure 6).[6,8]In fact, at a time when the academic system is becoming more demanding, rigorous, and competitive females are increasingly successful in STEM fields.[16] For example, females are publishing at a higher rate now than ever before in the most prestigious academic journals.[20] Based on publishing rates alone, females would be expected to be capable academicians. Even so, there exists a significant gender disparity in the upper ranks of faculty in academic medicine and STEM fields.[19,21] Interest in becoming an academician is heavily influenced by one's background, environment, and culture. The varying levels individuals have in exposure, encouragement, and expectations all impact their personal decisions to join academia.[14] For example, having a positive role model within a career contributes to an individual's ability to perceive one's self as successful within that career.[14,15]

Not only are there fewer existing female role models, but females also perceive additional barriers to achieving promotion in the faculty ladder than males do.[21] Role models and mentors have a large role in encouraging mentees to pursue and advance in academia.[22] With increased mentoring, students are more likely to follow their career aspirations, have higher salaries, publish more in academia, receive more grant money, and earn more promotions.[7] The perceptions between mentors and their mentees can have significant impacts. Females and minorities perceive the mentoring they receive to be inadequate and unequal to the level of mentoring they perceive that the majority of males have.[7] Females feel they are perceived as not as ambitious in their career goals by their mentors.[7] The expectations for females and males are thus categorically different to reflect this basic presumption that females are not trying to enter the academic faculty ladder as ambitiously as males. This presumption is rooted in a general societal expectation of a male being more likely to enter into academia than a female.[19] These expectations also results in mentors investing their time, energy, and resources in the success of their male mentees over female mentees.[7]

This preferential treatment for the success of males also leads to the self-perpetuation of the importance of one set of gender-specific personality characteristics over another.[15,19] For example, the stereotypical character traits of scientific leaders, including assertiveness and single-mindedness, are more so because they are characteristics of males, who populate the upper ranks of academia, and less because of their value in producing scientific knowledge.[7,10] At the same time, characteristics that are just as important for leaders in science and engineering, including flexibility, diplomacy, curiosity, motivation, and dedication, are less masculine and given less weight in the consideration of the potential success of an individual.[10] Societal influences contribute significantly to gendered behavioral traits through positive and negative reinforcement of behaviors. These societal influences act on females such that females who adopt the traits in academia face being perceived as “not nice” or “overly aggressive” while traditionally more accommodating females are perceived as “incompetent” and “trivial.”[10,23,24] These biases influence the behavior and decisions of females and males in academia by changing the natural behavior of more susceptible individuals and reinforcing incorrect stereotypes of traits that are important in academicians.

Systematic Exclusion of Females

Females who do choose a career in academia with the abilities and interests in becoming full professors are faced with a set of institutionalized practices and policies that systematically exclude them from being recruited, promoted, and retained. Though gender discrimination is illegal and outwardly frowned upon in academia, it remains widely practiced. Subconscious biases held by both males and females are deeply rooted in one’s background and become exhibited in one’s behaviors.[19] Several studies document this systematic gender-based discrimination.[10,25,26] In 1995, a committee of MIT professors reported gender-based discrepancies in lab space, amount of 9-month salary paid from individual research grants, teaching assignments, awards, inclusion on important committees, and assignments within the department.[25] A 1989 report from Johns Hopkins University (JHU) found problems in several areas including recruitment, salaries, campus security, and restrooms. Several of these issues have been addressed and currently, an on-going committee developed in 2002 is dedicated to assessing the status of females at the JHU.[26] Landman et al found that gender is a significant salary predictor; female physicians with the same academic ranks and practice settings as males earned on average $12,000 less per year than males.[7] Reasons for job dissatisfaction cited by females in academia included social and professional isolation in addition to gender discrepancies in the amount of funding, space, and staff support provided.[10]

The concept of social and professional isolation is extremely important and is also a form of gender discrimination practiced in academia. Informal “information networks” are often cited by many individuals as key to promotion and success in academia. Females feel selectively “left out of informal networks” of communication.[10] Exclusion can be more overt as well. Informal networks based on exclusion of “token females” have been known to play a role in deliberations for major departmental decisions, and the decisions are often made before official committee meetings.[27] Even a subconscious exclusion of females from these informal information networks may take a large toll on the opportunities that lead to successful academic careers.[10,14]

There is also a notable difference in the evaluation criteria to which males and females are held. “An impressive body of controlled experimental studies and examination of decision-making processes in real life show that, on the average, people are less likely to hire a woman than a man with identical qualifications, are less likely to ascribe credit to a woman than to a man for identical accomplishments, and, when information is scarce, will far more often give the benefit of the doubt to a man than to a woman.”(page 3)[10,19] Research shows bias often results in the work of females being less valued than that of males. A study of postdoctoral fellowships awarded by the Medical Research Council of Sweden found that female candidates needed substantially more publications to achieve the same competency rating as males.[14,28] Trix and Penska evaluated letters of recommendation for U.S. medical school faculty positions and found that female candidates systematically received less favorable recommendations than males due to gender alone.[10] In another study, peer-reviewed papers accepted more female submissions when the authors’ names were hidden.[29] In hiring processes, it has been shown that males are given the benefit of the doubt more than females.[10] In one study, female candidates were four times more likely to be asked to provide supporting evidence, such as a teaching demo or proof that grants were independently acquired, than males.[30] In other studies, department chairs tended to hire males and females with identical records to associate professors and assistant professors, respectively.[31] Martell showed that discriminatory practices emerged most when evaluators were under time pressures and were distracted during the evaluation process.[14] Thus, the systematic implementation of gender biases in a subjective evaluation system such as the hiring and promotion of faculty in academia can at least in part explain the lower recruitment and slower promotion of females. Though the biases employed are almost always subconscious, in an environment that favors the success of males, females have to contend with an accumulation of lack of opportunities and discouragement over time in an already extremely competitive career, and thus, the net effect of the systematic biases are magnified.[10]

The mechanism in place for recruitment, promotion, and retention of candidates in academia systematically excludes females from tenured and full professorship. The policies (or lack of policies) are clear of any overt discrimination; however, their implementation often results in the preference of male advancement over females.[15,16,32] Academicians in medicine have three main roles: clinician, researcher, and educator. Academicians in STEM fields teach and do research. These multiple roles create a delicate balance for academicians to observe in order to be accomplished in their profession. Any time spent educating and seeing patients as a clinician decreases the amount of time one has to spend on research productivity. Following this, the less productive one is in research, the fewer publications one will have. Publications are the most valued criterion in the rubric of promotion that is currently in place in academia. Thus, it is critical to spend time doing research in academia. On average, females spend more hours teaching and doing clinical work than males.[23] One reason for this is that the jobs given to females are not geared towards promotion in academia, automatically limiting the chances of females to become ladder faculty.[23] Another reason is that females are not part of the information networks or do not receive sufficient mentoring early on in their career to make the appropriate choices about the types of jobs they are accepting or path they are pursuing in order to excel in academia.

Faculty surveys show that more female than male faculty feel that their department undervalues mentoring as important roles of academic professionals. They also report having poorer relationships with their mentors than males.[10] The reasons for these assertions are either females receive less and lower quality mentoring than males and/or females expect more and higher quality mentoring than males. Regardless of the reason, the inadequacy or lack of structured mentoring systems in academia has had a larger effect on females than on males.[14] Mentoring is clearly cited as a contributor to career advancement in academia, and lack of sufficient mentoring for females is systematically reducing their chances for success in academia.

Finally, the criterion applied for hiring and promoting by academic institutions is openly and admittedly subjective. The candidates' ability to interact in harmony with the other members of a department is important, and thus, there is significant value placed on the subjective opinions of candidates by the hiring committee. The existence of an objective rubric that is applied equally on all candidates by all members of a hiring committee is rare.[19] Such a system leaves ample room for subconscious (or conscious) biases to play out. Part of the reason for this is that it is extremely difficult to quantitatively measure the qualities that make for good academicians, such as intellectual curiosity and dedication. Assumptions must be made based on accomplishments and one's personal interaction with the candidate. Qualities such as assertiveness and single-mindedness, traits that are less common in females, are often selected in this environment because of the obviousness of those traits in individuals and the subconscious value they have in the minds of the hiring committees.[10] Hiring committees do little to prevent their own subconscious biases from having an impact on their hiring decisions.

The Outdated Model of Academia

As discussed, retention of academicians is more than just a gender-discrimination issue. It is of great benefit to the institution to determine where and why females are leaving their academic positions. When a faculty member leaves, institutions incur extensive costs that can result in significant instability of a department.[33] Depending on the instance, faculty can also become demoralized. Nationally, there is a declining interest of MDs and PhDs to join academia over community or industry practice.[34] One factor that contributes to decreased retention is the academician life-style. "By its nature, academic work is potentially boundless: there is always one more question to answer; one more problem to solve; one more piece to read, to write, to see, or to create "(page 22)[10,35] Within any given field, hours are usually better outside of academia, which currently tends to be more important for females than males (although, the importance males are placing on this in career-determination is also growing).[21] Also, and arguably more importantly, the academic system is not optimized for productive potential or retention.[10] The academic system was developed in a society that is based on an out-of-date male life course – that one's reputation in society is based on their success in career and there is always someone at home to provide the necessary life and family support needed.[10] Evidence indicates that anyone lacking the work and family support traditionally provided by a "wife" in this out-of-date model is at a serious disadvantage in academia.[23] However, the majority of faculty (male and female) no longer has such support. About 90% of the spouses of female faculty in science and engineering are employed full-time; close to half of the spouses of male science and engineering faculty also work full-time.[10] Because more females have full-time working spouses, they are at a larger disadvantage than males in the current academic system. This becomes a serious issue for the retention of females in academia. Ten years into their careers, high-tech companies found that 41% of females had left their careers, compared to only 17% of males.[15] In one attrition study, males focused on low pay and the lack of career advancement for why they chose to leave academia, while females cited, among other things, managing their home and career.[10] At the same time, many individuals experience these hardships and stay in academia, which translates to lack of job satisfaction for more senior faculty and trickles down to discouragement for junior faculty or medical and graduate students to pursue academic careers.[10]

Additional barriers for female progression in academia commonly cited in literature include the lack of accommodation of childbearing and caretaking responsibilities that largely fall upon females. [2,11,12,23,36-39] A committee at Columbia University determined that family responsibilities disproportionately impact females in academia, in that female faculty tend to have fewer children than male faculty and carry most of the childcare responsibilities.[27] Females are in their childbearing years at the same time as the most strenuous and demanding portions of career development in academia, and thus, there is a conflict with time allocation towards work versus family. Institutions with stop-the-clock maternity leave, child-care options, and spousal hiring programs are more aware of this conflict and these interventions play a significant role in female faculty retention. Academic institutions are not the only groups that females often have to contend with to meet their full responsibilities. Females still bear the brunt of family-life expectations put on by society for understanding social connections between family and other institutions— such as church, day care, schools, health care, and banks.[10,23] In each of these, the understood responsible party in the family is usually the female spouse, and thus, the time needed to handle each of these also contributes to time away from academic work.

In hiring and promoting, several studies show that a measurable difference exists among females with and without children and females and males with children. Mason and Goulden showed that females with children are 50% less likely to gain faculty positions than single females or males with children.[40] Ginther found single female scientists and engineers were 16% more likely than single males to be in tenure track jobs five years after receiving their PhD; however, married females with children were 45% less likely than married females without children to be in tenure-track positions.[17] Having children, especially young children, decreases the likelihood of females obtaining a tenure-track job by 8% to 10% in all science and engineering fields but has no significant effect on the rate of males joining the tenure-track.[10]

This disproportionate disadvantage for female academic scientists and engineers with children is attributable to the academic institutional devaluation of femininity and motherhood at their core. This devaluation results in a bias against caregivers that is deeply embedded in the practices and policies in academia.[10] Research shows mothers, potential mothers, and fathers who seek an active role in family care are penalized more than males who do not seek an active family life. The researchers document that females experience gender stereotyping in "how jobs are defined, in the standards to which they are held, and in assumptions that are made about them and their work." For example, a male who is absent is assumed to be presenting a paper, whereas a female who is absent is assumed to be taking care of her children. Mothers also face negative assumptions about their competence, specifically, that they are less competent or committed than other workers. Similarly, fathers who take parental leave or even a short leave to deal with family matters often receive fewer rewards and lower performance ratings and are viewed as less committed to their careers than men with children.

Another practice that affects females with family responsibilities includes that of punctuality and the unpredictability of meeting lengths. Individuals who live with tighter time restrictions because of other serious commitments find it more difficult to plan around such haphazard scheduling. A new norm that establishes expected punctuality and definite meeting end times makes the environment more congenial to academicians with significant outside responsibilities.[10] These good business practices also enhance the productivity and efficiency of an organization.[27] One new advent of a career choice that has been gaining popularity in the last ten years is that of part-time employment and the adjunct professor track. Part-time employment includes positions that carry fewer hours of work than a full-time job. Adjunct professors are hired on a contract basis instead of a salary. Both have significant stigmas associated with them that make it much more difficult for individuals to become promoted in to tenure-track positions if they ever gain the desire to. Some of these stigmas include a failure to keep the pace or failure to obtain a job right after graduate school. Adjunct professors are marginalized even more because they maintain significant time commitments to their academic job, working for greater than 50 hours/week on educating future generations of academicians, but their value is not reflected in the tenure track system that promotes only researchers.[41]

Mentorship in the current academic system is completely informal and not rewarded monetarily or consistently in promotion discussions. This affects both females and males; however, evidence shows that females and males value different mentoring relationships.[7] Societal influences leave females more conditioned to measure their value of their achievements by the amount and nature of the feedback they receive; males, on the other hand, are taught to expect little feedback. In graduate school, where much of the work is self-guided and little praise is given, females are more vulnerable to losing their self-confidence. Direct encouragement and praise is much more effective on females than on males.[10,14] Also, studies show that students and mentors feel more comfortable when paired with people of the same gender and ethnicity.[10,27] Especially with issues of inequality, dissatisfaction with workplace environment, pressures of being a minority, lack of females in academia, and subconscious biases by evaluators, females feel more confident discussing these issues with people who may have had similar experiences.[15,28,29] The underrepresentation of senior females and minority-group faculty at the upper ranks makes it difficult for junior faculty and medical and graduate students to find appropriate mentors.[10,14] The long-term, intangible benefits of mentoring, including attracting more students, developing one's professional network, and staying up-to-date with one's field through informal means, are especially hard to realize when faced with the immediate tangible consequences of an increased time commitment burden.[10]

Females as Minority Groups

The underrepresentation of females in academic medicine and STEM graduate fields manifests itself as a problem for other reasons as well. The issues that minorities groups face are well established in research. By their very nature, minorities have fewer opportunities to compare experiences, receive assistance without being judged or fear of being judged as inadequate or lacking, obtain advice for whatever situations that may arise, receive peer support, and build their professional networks. A significant disadvantage that underrepresentation confers is workplace bullying. Bullying can be defined as "an abuse or misuse of power characterized by work-oriented aggression and is distinct from sexual harassment in nature and target of the aggression." Bullying behavior is often systematically applied to females and can persist even in the highest levels of the academic hierarchy. Work-related bullying may involve excessive assignment of work, reassignment of responsibilities, unfair criticism, and excessive monitoring. Newcomers are often targeted, particularly those from groups not well-represented in the workplace.[10,14] The idea of a "critical mass" has often been cited as a countering force for this issue. Once the percentage of females is 20% a change in environment is observed. Females start to perceive their common interests and join to advocate changes in policies. They also begin to appear in leadership positions. At this point, overt discontent from males may also begin to manifest itself. As females become an established threat to the traditional order, males subconsciously, or even sometimes consciously, retaliate in the form of bullying.[10]

As female representation grows to 40%-60%, gender issues seem to attract less attention. At this point, gender equality issues do not arise as much and a decrease in all hostility is also observed. However, at 90% gender issues return. A female dominated department is automatically seen as less prestigious than otherwise. This comes with real consequences such as poor pay and loss of societal acclaim. Interestingly, females are often working at the fringe of their fields because the overcrowding of males in the traditional research areas makes it difficult for females to advance academically. At University of California, Berkeley, once the Biology department was restructured to include the various areas of research that were more integrative and less "pure" Biology, the department had an almost equal number of males and females. At this point, individuals also cited that their department lost its prestige relative to other departments.[10]

What has been tried already?

Several of the issues discussed until now have already been addressed through a variety of programs and initiatives with varying levels of long-term success. The overall goal of these programs has been to increase the number of females in academic medicine and STEM fields. Reports from committees at universities have contributed to an informational change in the atmosphere around addressing this issue. The responses are not always positive though. At MIT, Nancy Hopkins, chair of the first Committee on Women Faculty in the School of Science, stated that feedback to earlier reports on the status of female faculty at MIT had been positive from selected individuals, but there are many administrators, who despite the data presented and the investment of key leaders at MIT, still believed that there are no gender biases in academia.[25] She attributes this to the deep socialization of discriminatory attitudes towards females that will take hours of education and years of experience to reverse. Even so, universities have addressed hiring and retention with specific policies that decrease the systematic exclusion of females. With these policies came an influx of female professors. At MIT, 80 new female professors were hired in a span of five years following the institution of these policies. Though significant progress has been made, new prejudices begin to form among peers and supervisors and take a toll on the new females who have been hired since the affirmative action policies have been put in to place. These prejudices are based on the idea that females are perceived as being hired at a lower standard than their male colleagues by themselves and their peers. This assumption is a result of the socialization within our community and is an expected reaction to the action of an increase in hiring females after a long period of stagnation. Even still, these issues have serious repercussions in an academic environment where one's collegial network is highly determinant of one's success in academia. Problems that were more difficult to predict included the sense that female faculty felt it was difficult to reach out to other females as mentors. Also, female faculty felt over-committed on service organizations and institutional committees that they were assigned to as part of the new policies in place to ensure females were not being excluded from hiring and promoting in academia. At the same time, they still continued to feel left out of the process for making important institutional decisions, in part due to the informal networks of that existed.[42,43]

In general, when numbers of minorities are increased to between 20% and 40%, it can bring about adverse reactions from colleagues, as previously discussed.[14] The attitudes and reactions are fairly predictable but the exact nature truly depends on the personalities and mentalities of the established group of members and the relative proportion of newcomers to the group at large. For example, sometimes current members of a group engage in bullying or threatening behavior, and at other times, they are more welcoming and supportive. The reactions evolve as the proportion changes. There is also evidence, however, that efforts to change the mentality of the established members contributes towards deterring negative reactions and attitudes.[10] This area of intervention takes the form of diversity education programs for university faculty.

Another area commonly targeted for interventions is family life. This topic receives significant public attention and is thought to be the main culprit whenever the issue of gender disparities in academia is raised; however, it is important to note that several issues that contribute to gender disparities are not rooted in family life issues. Several females without children face barriers to promotion in academia simply because of their gender and not their role in their family. Individuals who are interested in high-level academic careers are generally well aware of the academic bias against caregivers.[7] A number of strategies are employed by individuals to keep family responsibilities from damaging their careers. One is to minimize family commitments.[7] The most obvious method is avoiding marriage and parenthood. Overall, 17% of females at research universities stay single, as opposed to only 10% of males; 30% of females versus 13% of males have limited their number of children to avoid anticipated career damage; 18% of females versus 8% of males have delayed their second child for the same reason. Institutions recognize this dividing factor between males and females and many permit faculty members to request that the tenure clock stop for a period of time or that their workload be temporarily lightened to mitigate the career effects of childbearing and childrearing. Many academicians, however, fearful of seeming to lack dedication and seriousness to one’s career, decline to avail themselves of these opportunities. For example, over a 7-year period at one large research university, only four parents of either sex, of the 257 on the tenure track, took advantage of official family leave. That statistic typifies the tactic to deflect attention from one’s family responsibilities. Other tactics include missing children’s events and returning to work earlier than medically advised after a birth. Studies show that more females than males engage in these tactics, which adds to their stress and the overall unattractiveness of an academic career for females. For faculty—males and females—who engaged in bias-avoidance behaviors, time to tenure was reduced and age at tenure was reduced by over a year.[10]

The Pregnancy Discrimination Act of 1978, which forbids treating pregnancy differently than other temporary disabilities, exists to deter such discrepancies observed in academia. However, one third of universities have policies and practices that appear to violate the Pregnancy Discrimination Act. Female—and, in some cases, male—academicians who try to assert their rights under such laws as the Family and Medical Leave Act, which mandates 12 weeks of unpaid leave and the right to return to equal standing at work, often find themselves pressured to return sooner than they wished and face increased scrutiny, adverse career consequences, and other forms of retribution, if they choose not to. Legal enforcement of one’s rights can have serious repercussions on one's career. Certain strategies have employed legal enforcement of established anti-discrimination policies to affect change. For example, one institution cited an increase in the number and accessibility of athletic programs for females using legal enforcement of anti-discrimination policies. Title IX, the federal statute that prohibits discrimination based on sex, has been used to threaten to withhold federal funding to institutions who fail to hire more females in science and engineering than they had been.[10]

The National Science Foundation's (NSF) own progressive initiative, the ADVANCE program, began in 2002 and focuses on transforming the policies, practices, and climates for faculty in U.S. research institutions to one that is unbiased towards gender. It gives grant money to leading institutions to determine best policies and practices that give results in altering the climate and fostering a conducive environment towards, among other things, the promotion of females in academic institutions.[6] Several sites have developed practices that have proven effective to date to increase the strength of their female candidates for advancement in academia.[14] Many of these focus on mentorship strategies, elucidation of subconscious biases, and general improvement of working environment through clarification and enforcement of productive policies.[14] Mentorship strategies outside of the traditional 1-on-1 model that is commonly employed in academia are gaining popularity. One type of mentoring is called group mentoring in which a group of faculty members is assigned to be mentors for a particular student or junior faculty. This strategy seems to do more to ensure that females have mentors and has been reported as successful thus far, however it only addresses the formal mentoring issue and not the informal networking issue that females often feel isolated from.[7,14] Awareness of subconscious biases is another targeted intervention. Awareness does not always translate into change. For instance, though it is known that name-blinding on applications or journal articles increases the rate of female acceptances and hires, that practice is rarely employed.[14] Education and awareness of these biases and their effects is still important, and group education sessions help to validate suspicions that gender discrepancy is in fact a problem. These initiatives to educate bring the issue of subconscious biases and the importance of diversity in academia to the forefront of thoughts of members of hiring committees who otherwise would not have thought about it.[7]

The fact of the matter is that there are several issues related to the progress of females in academic STEM and medicine fields. No one factor can attribute to the significant discrepancy observed between males and females, but all factors combined contribute significantly to the overall systematic exclusion of females from hiring, promotion, and retention in academia.. Identification of the problem affects the design and implementation of interventions that are meant to improve the system for advancement of females; however, they also have unintended consequences. Thus, prudent, consistent, and detail-oriented analyses are paramount in order to develop the most effective interventions for this system. There are a myriad of ways to study social systems as complex of this. In general, a comprehensive, large system analysis of females in STEM and medicine academia has not been conducted on this topic.

Section 2 Statement of Purpose, Specific Hypothesis, and Specific Aims

Statement of Purpose

Though significant research has been devoted to gender disparities in academia,[44] underrepresentation of females remains a significant problem in STEM and medicine academia, especially at the upper ranks of faculty. Significant inequalities persist despite the implementation of many interventions.[45,46] What we do not know about gender disparities in academia is: 1. whether the attributed causes are an accurate representation of why the inequality exists in the system; 2. whether we are focusing on the right interventions; 3. if there is a better way to increase diversity; and 4. how much and where the true fallout of females from the pipeline is occurring.

These questions are difficult to answer because of the myriad of components of the system interplaying in a way that renders the issue of female underrepresentation in academic STEM and medicine extremely complex to analyze. Historically, this problem has been studied in a static, linear model which does not allow for recursive or dynamic relationships, limiting the depth at which these issues can be understood. The classic cycle of systemic issues affecting individual choices that then lead to reinforcement of the current system is taking place. Though this is a self-perpetuating cycle, the system is responsive to interventions. Research that explains the interrelationship among the various components of the system of female underrepresentation in academia is needed. This research can then be used to develop a more comprehensive understanding of the system in order to design and carefully implement effective interventions. Understanding that female underrepresentation in academia is a systemic issue, this research asks the question of "how" instead of the traditional inquiry of "why."

Specific Hypothesis

The relative rate index is a better tool for detecting and measuring system changes in gender disparities in academic medicine than percentages.

Specific Aims

To identify whereat in the system, by rank and by department, females are dropping out of academic medicine at Yale using a relative rate index.

To establish a model that identifies the underlying mechanisms that results in underrepresentation of females in the STEM and biomedical workforce.

Section 3 Methods

Institutional Review Board (IRB) approval

IRB approval was obtained for the working groups and interview portions of this study.

Relative Rate Index (RRI)

In order to determine whether there is an actual discrepancy in academia among the hiring, progression, and promotion of males and females, several quantitative methods of comparison can be employed. First, a simple numerical analysis can determine the relationship between the absolute numbers, e.g. absolute number of tenured males exceeds the absolute number of tenured females. The next calculation is to convert the absolute numbers into percentages which gives an easier interpretation of the relationship between the absolute numbers of males and females. In doing so, the total population size of professors is lost. Still, taking percentages one step further, a temporal analysis can be made by comparing percentages over many years and analyzing those trends. In general, trends over time is the extent at which analysis in this area using percentages is done (Figure 1 and Figure 2).[5]

Though trends are important, percentages are inadequate for determining gender discrepancies in academia because it does not take in to account the process of hiring and promotion that leads to those percentages. In order to do so, it is necessary to consider the context in which percentage disparities have occurred. For example, many universities have adopted policies to reduce gender disparities in academia; however, since the hiring and promotion process is so lengthy, the system may be skewed towards hiring and promoting only females for several years before that will be reflected in percentages.[42] In other words, the way percentages are interpreted leads to the conclusion that gender discrepancies in the hiring and promotion process favor males when, in fact, the opposite may be true for several years before the percentages change to reflect it. Thus, a calculation is necessary that takes in to account the change in advancement relative to males. Focusing solely on the percent of female full professors compared to the percent of male full professors is an insensitive measure of actual system change. Given that the route to full professor is through promotion from associate professor (Figure 7), it is necessary to measure the context in which associate professors are promoted to full professor. Subsequently, an analysis of associate professors would measure the context in which assistant professors were promoted to associate professors. Thus, a superior and more sensitive measure of gender disparity is to consider the number of females promoted relative to the number of available females eligible to be promoted from the previous rank and compare this to the same calculation done with males. This calculation creates a more robust data set to analyze by offering information on the surrounding circumstances that lead to the percentages observed, and thus a more informed perspective overall.[47] To date, no such analysis of data has been conducted in this area.

The Relative Rate Index (RRI) is an established measure used for comparing sub-populations that are progressing from one stage to the next within a system. It is a more sensitive measure to identify progression through a system because it takes into account the percentage of the sub-population in the stage directly prior. This becomes important when trying to determine exactly what stage the sub-populations diverge in progression from one stage to the next.[48] For example, if one population begins with 200 males and 100 females, then one would expect a 2:1 ratio of males: females in the final stage if there were no gender-based biases impacting the system. In such a scenario, the RRI of the system would be equal to 1, which represents equality of progression among sub-populations. Thus, it is a comparison of the proportional advancement of the sub-populations rather than the absolute quantities at each stage. RRI also standardizes the data for ease of interpretation. If the ratio of one sub-population to another is not maintained, then the RRI is equal to one, and if not, then one sub-population is being advanced at an increased rate relative to the other. Less than or more than one indicate a fewer or greater number females progressing relative to males in the academic faculty ladder, respectively.

If there were no gender-based discrepancies in academia in the past or at present, one would expect to see 50% females at every professor rank since slightly more than half of the U.S. population is female. Due to gender roles and discrimination, many medical schools did not admit females. In 1972, Title IX of the Higher Education Act prohibited discrimination based on gender, and even then only few females were admitted.[49] Yale University only began admitting females to medical school in the 1970s as well. The current senior ranks are predominantly male simply because of this historical advantage. There are fewer female full professors because they were not trained during the time period when most of the male full professors were trained rather than they are not promoted from the associate professor ranking at an equal rate. Thus, it is difficult to determine whether any progress has been made by looking simply at percentages for this population. Using RRI, population information of all the ranks can be used to determine if the current data reflects any gender-based imbalances in promotion in the faculty ladder and where they are occurring.

Previously, RRI was used in evaluation of juvenile delinquents using sub-populations based on race. Criminal justice researchers found that relying on percentages of African Americans and Latinos in prisons did not adequately explain where in the criminal justice system racial disparities existed and where in the system minorities were more likely to receive differential treatment. An RRI analysis shows how minorities are more likely to progress through each step of the criminal justice system relative to whites, and it helps determine where the largest racial discrepancy lies. [50] RRI makes this information readily discernible in the form of a matrix of ratios, where 1 is equal to no discrepancies based on race (see Table 1). Modeling the present study on prior racial discrimination studies in the criminal justice system of minorities, we apply the RRI technique to identify underrepresentation of females in the academic ranks of assistant, associate, and full professor. A corollary calculation in clinical medicine is called Relative Risk (RR). RR is the calculation of the ratio of an event occurring in an exposed group versus the ratio of it occurring in a non-exposed group. The events are usually diseases, side effects, or positive therapy results. Using the same terminology as RR for measuring gender discrepancies in academic medicine, the event occurring would be promotion to the next level, the exposed group would be females, and the unexposed group would be males.

In summary, it is inadequate to focus solely on percentages to measure the underrepresentation of females in faculty ranks in academic medicine without a clear understanding of the context within the system that led to these disparities. Even if effective mechanisms are put into place to remedy this disparity, it will take several years of implementation to be reflected in percentage calculations. Thus, a superior measure calculates intermediate rates of advancement in the faculty ladder and compares that of females to males, which RRI promises to do. In order to test this hypothesis, the percentage and RRI calculations of females and males in each stage of the faculty ladder is presented. The traditional approach of percentage calculations for analyzing the gender discrepancies is then compared with RRI in their ability to identify where and how much females are not progressing relative to males to demonstrate the differences in these metrics.

Data

Data for this study comes in the form of a total census (rather than a sample) of males and females for professors by rank and by academic medicine department (N = 1305). The Yale provost's office provided institutional records on the breakdown of males and females in the ladder faculty tracks for all 30 departments and centers of interest and in all tracks as of July 16, 2011. The gender breakdown for location prior to entering ladder faculty positions (e.g. postdoctoral fellowships, residents, etc.) was not obtained. The data was provided in a spreadsheet with filters set for each department and center of interest. This data was copied and pasted into another spreadsheet for further analysis. In order to maintain the anonymity of faculty members, the total population of faculty members at a particular faculty rank for any department is never presented at any point during this study.

Analysis

First, the faculty tracks were combined for each department to obtain populations for each of the following three ranks: assistant professor, associate professor, and full professor. The assistant professors in the Traditional, Clinical Educator, Clinical Scholar, and Investigator tracks were combined to give the total for assistant professors. The associate professors in the Traditional (Term), Clinical Educator, Clinical Scholar, and Investigator tracks were combined to give the total for associate professors. The tenured associate professor in the Traditional track was combined with the full professors in the Traditional, Clinical Educator, and Clinical Scholar tracks to give the total for full professors. Female percentages were calculated by dividing the number of females in each position in each department by the total number of faculty in that position. Male percentages were calculated similarly but using the number of males in each position in each department. Subsequently, at each level, the number of departments that fell within a certain range of percentages were grouped in order to show the distribution of departments relative to their female representation at each faculty rank.

In order to gain insight into the percentage of females in each department as one moved up in faculty rank, four plots were constructed using “up” and “down” to indicate the direction of female representation from one step to the next:

- Down from assistant to associate, and then down from associate to full professor
- Down from assistant to associate, and then up from associate to full professor
- Up from assistant to associate, and then down from associate to full professor
- Up from assistant to associate, and then up from associate to full professor

Each department was graphed on its respective plot, depending on the nature of their female representation as one moved up in faculty rank.

Subsequently, two plots were constructed using the number of faculty in each department. The first is a box and whisker plot that graphed all the numbers of faculty in all the departments at each level. This graph is constructed by calculating the median, 25th and 75th percentiles, and the full range for each gender at each level. Then, the median was represented as a solid line, the 25th and75th percentiles marked the lower and upper edges of a rectangle surrounding the box, and solid lines extended above and below the rectangle to represent the extent of the range. The second plot takes an average of the number of faculty over all departments in each gender and graphs those per level of the faculty ladder.

Next, RRIs at each step were determined using the following formula:

Female Percentage: X   Male Percentage: Y

Stage 1: X_1, Y_1

Stage 2: X_2, Y_2

Stage 3: X_3, Y_3

RRI of Females to Males from Stage 1 to Stage 2 $= (X_2/X_1) / (Y_2/Y_1)$

RRI of Females to Males from Stage 2 to Stage 3 $= (X_3/X_2) / (Y_3/Y_2)$,

where Stage 1 = assistant professor, Stage 2 = associate professor, and Stage 3 = full professor

Percentages used in the relative rate index calculations are the same that were calculated for the percentage analysis done earlier. Once the RRI of each department for each step is calculated, a matrix is created for ease of comparison (see Results section). Analysis of the matrix is conducted using the guide provided in Table 2.

Table 2 RRI value and its meaning.

RRI	Interpretation
1	There is an equal rate of progression of females and males from one level to the next.

< 1	There are fewer females progressing relative to males given their representation in the prior level.
> 1	There are more females progressing relative to males given their representation in the prior level.
0	There are zero females progressing and a non-zero number of males progressing.

The RRI can also be undefined. In that case, there are either zero females represented in the prior level or there are zero males represented in the subsequent level. The departments that did not have an undefined value were subsequently graphed on a plot of RRI vs. step in ladder faculty. Two graphs were constructed: one to show the RRIs that increased from one step to the next, and the other to show the RRIs that decreased from one step to the next.

System Dynamics (SD)

There are a plethora of factors acting on the system of academic advancement that are important to consider when studying the academic promotion system. Many factors with no obvious quantitative correlations are largely ignored. Other factors are considered independently instead of comprehensively as part of the entire system.[51] A thorough analysis that includes all the relevant factors is extremely important to conduct in a social and dynamic system such as advancement in academia. Within this field in particular, there are several cause and effect relationships with multiple intermediary steps that are better visualized within a model and can easily affect one's understanding of the underlying mechanisms for why females are underrepresented in academia. In contrast, traditional statistical models are both static and linear which does not sufficiently fit the social structure of academic advancement.

In order to do a comprehensive and holistic analysis of the system of ladder track faculty promotions in academia, a modeling technique referred to as system dynamics (SD) is employed.

System dynamics is an approach for understanding, designing, and managing changes in complex systems using computer modeling and simulation.[52,53] Developed at Massachusetts Institute of Technology by Forrester in the 1990s, it has been used as a tool for assessing complex systems in many fields, including industrial, commercial, and healthcare. [54,55] The models generated using this approach can represent both temporal and causative relationships among variables mathematically and pictorially, including tangible (e.g., number of people, salaries) and intangible elements (e.g., biases, access to information). These models draw on a wide range of qualitative and quantitative data sources.[53] As a result, these models are extremely powerful.

SD modeling allows for non-linear modeling of complex systems. Non-linearity describes a system in which the status of the end-product(s) has an effect on one of the preceding factors. In a linear system, the end product does not have any influence on factors preceding it. An example of a linear system is fee-for-service insurance policies. In a fee-for-service system, unit fee of service multiplied by the services offered per year is equal to total charge of service per year. In this model, the total charge of services per month has no bearing on what the doctors' unit fee of the service is or on the number of patients who receive that service. An example of a non-linear system is the capitation system. In a capitation system, there is a capitation on the amount reimbursed for a particular service in a year. The value is dependent on the number of potential patients served. The total charges of services per year scales linearly as under the fee-for-system until this value is reached. Before the capitation value is reached, there is a large incentive to provide this service to try to reach the maximum potential revenue obtainable. Once that value has been reached, there is less of an incentive to provide this service, and hence, as the year progresses, the changing amount of total charges has an indirect effect on the rate of service provided. This relationship cannot be adequately described using linear modeling.

Most systems in real-life are non-linear; however they are often simplified to a linear model for ease of analysis. Oftentimes, such simplifications undermine an overall understanding of the system whereby the effects of changes, or interventions, on the system are no longer predictable. Modeling non-linearity is often more robust and representative of the real world.[56] In order to determine equations for the model, many controlled studies and deliberate data collection are required. Doing so will lead to the ability to maximize the benefit realized from SD modeling in analyzing complex systems.[57] Without these equations, the model that is developed is still useful. The inter-relationships among the factors are pictorially represented in one diagram, so downstream effects of changes in the system can be easily visualized and the underlying mechanisms for the underrepresentation of females in academia are better understood.[57] This diagram is called a causal loop diagram and is specifically constructed to show through visualization how interrelated factors affect one another.[58]

Data

The goal of SD modeling is to identify the underlying mechanisms that explain why females do not advance in academic medicine, and the interrelationships among them. Initial factors that explain females progressing through the academic pipeline were first acquired from a preliminary content analysis of existing research. This content analysis was an ongoing process throughout this study. Eventually, over 50 papers, reports, and books were analyzed and included in this study from a variety of academic disciplines including economics, medicine, science, engineering, and sociology. These sources were also used to obtain the linear models that are used for comparison against the SD model. The results of each study were used to identify the essential social factors that were being tested with their research questions. Sometimes these were explicitly stated as part of the study and other times they were a part of the inferences discussed in the conclusions. Then, any other stated factors that may have contributed to the results observed in the study were identified and recorded along with their relationships to the study factors.

Next, a group of expert faculty members were consulted to help elucidate 1. additional factors not obtained from the content analysis, and 2. more details about the nature of the effect of one factor on another. A semi-structured interview schedule was used to direct the group (see Appendix A). A scribe was present who coded the information with written notes and the session was digitally recorded and then re-played until no new information was gained from the discussion. A total of eight Yale faculty participated in this working group, including one female from a different university to increase the diversity of the perspectives on this issue. Further data collection was obtained from conducting 1-on-1 interviews with gender disparity experts to probe deeply into certain aspects of the system. Each of these sessions were also recorded and re-played for thoroughness. Six 1-on-1 interviews were conducted. Data collected came in the form of anecdotes, studies, and observations. Each was coded for the essential factors they represented and in what context they arose. Relationships among these were determined through listening for content and context. Opposing viewpoints rooted in varying personal experiences were brought up and discussions of them elucidated more cause and effect relationships among the various factors.

Finally, the model that was constructed with the information obtained using content analysis of literature, a group meeting, and interviews and was presented for the purpose of validation and confidence building in a second group meeting of expert senior faculty. In this meeting, the model was shown, inter-relationships were explained, and feedback and comments were collected. This process allowed for group consensus of the interrelationships constructed and to build confidence and clarity in the causal loop diagram as a whole. This interaction was also recorded and re-played to ensure that all the feedback obtained was reviewed and reflected in the SD model. Seven females participated in the second group meeting, including five who had been present in the first one. The process of continuous information gathering and model revision was conducted until no new information was apparent, also known as saturation.[59] This process incorporates well-established method for building such social and dynamic models.[60,61]

Analysis

First, the results of several published studies of the static, linear models found in literature are included to be subsequently used for comparison with the SD model. These studies often did single or multiple factor analysis comparing males and females in an issue that is part of the system of underrepresentation of females in academia. Next, the information from the content analysis of all the literature, the group meetings, and the interviews led to the identification of additional factors and interrelationships. The interrelationships that were identified were entirely qualitative and no equations were written to represent them. However, many of these relationships have been empirically tested in quantitative studies as the ones included in the first part of this analysis that reported the results of static, linear models found in literature. To build the SD model, the factors are compiled into one diagram and subsequently divided in to smaller constructs for ease of interpretation. The overall model and smaller constructs all share the same notation scheme and use the same mode for analysis. All factors are color-coded to indicate which smaller construct that factor is most associated with. Factors that overlap among smaller constructs maintain the color of the construct they are most associated with. This mechanism is useful in visualizing the amount of interrelationships among several smaller constructs that exists in the model. There are a few factors that exist in all or almost all smaller constructs and those factors are black and have a hexagonal border.

Arrows show cause and effect of one factor on another. The effects can either be positive (exacerbate the downstream factor) or negative (reduce the impact of the downstream factor). This relationship is indicated with a + or – sign located at the head of the arrow. The factors that represent interventions have a rectangular border and have the understood input factor of "underrepresentation of females in academia," which when increased leads to an increase in the interventions. For analysis, one can start from the rectangles and follow their downstream effects to understand the complete impact of the many interventions that have been tried to increase the representation of females to date. The overall model was analyzed in a similar fashion for relationships among factors that were not previously stated but were apparent within the model by following one factor that led to another factor until the downstream effect was realized.

Loops that were formed that created an overall positive reinforcement of the effect of the main factor on the system are called “reinforcing” loops, labeled with an “R.” An example of a reinforcing loop is more people using Kindle leads to more people talking about the benefits of and seen using Kindles, which leads to more people purchasing Kindles, which leads to more people using Kindles. Loops that show self-inhibiting patterns are called “balancing” loops, labeled with a “B.” An example of a balancing loop (building on our previous example) is more people buying Kindles leads to more people who have Kindles, which leads to fewer potential purchasers of Kindles, which leads to fewer people buying Kindles (also known as market saturation). These types of relationships are not evident in the static, linear models as they represent the non-linearity that makes SD modeling useful for a more comprehensive understanding of the system of female underrepresentation in academia.

Information gathered from the model includes the downstream effects of certain interventions, the potential for synergism of interventions, possible reasons for why past interventions may have failed, and suggested areas for intervention and more research. Linear models offer explanations for a decrease in the number of females seen in academia as well. They also offer ideas for how interventions will work. Possible reasons for why past interventions may have failed can be determined through comparing the SD model to the linear models of studies found in literature.

This work was entirely conducted by Nupur Garg.

Section 4 Results

Percentages Results

On July 16, 2011, the current number of ladder faculty in each rank in a total of 30 departments and centers was obtained from the Yale Provost's Office by gender. The centers were removed from the study to eliminate double counting dually-appointed faculty and percentages are calculated for 22 departments, individually and overall (see Table 3). The total sample size was N = 1305.

Table 3 Percentages by Department

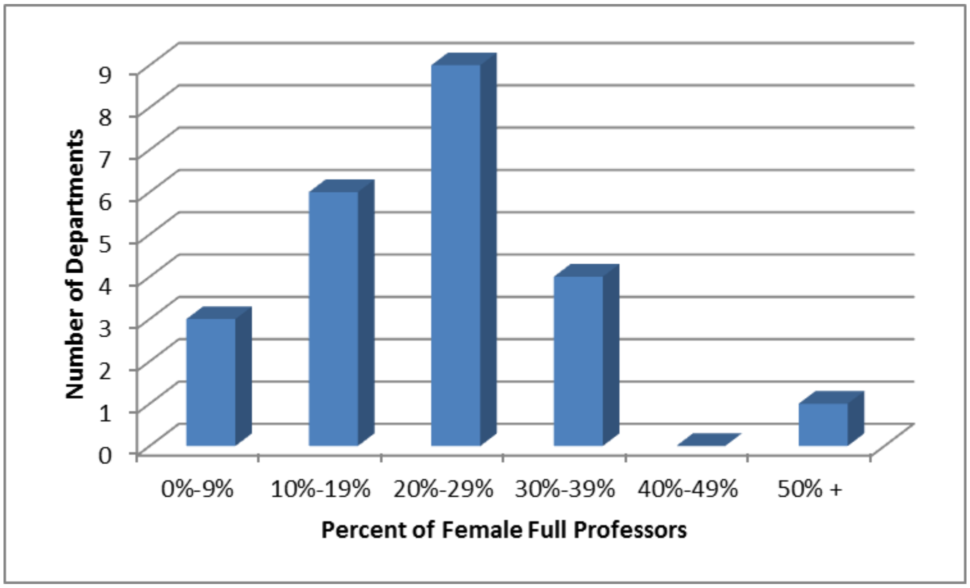
Departments	Assistant Professor		Associate Professor		Full Professor	
	Females	Males	Females	Males	Females	Males
Anesthesiology	0.56	0.44	0.33	0.67	0.23	0.77
Cell Biology	0.11	0.89	0.00	1.00	0.29	0.71
Dermatology	0.50	0.50	0.43	0.57	0.33	0.67
Diagnostic Radiology	0.41	0.59	0.20	0.80	0.24	0.76
Emergency Med	0.44	0.56	0.60	0.40	0.50	0.50
Epid/Public Health	0.75	0.25	0.50	0.50	0.39	0.61
Genetics	0.25	0.75	0.50	0.50	0.33	0.67
Immunobiology	0.50	0.50	0.33	0.67	0.10	0.90
Internal Medicine	0.53	0.47	0.41	0.59	0.21	0.79
Lab Med	0.33	0.67	0.20	0.80	0.33	0.67
Mol Biophys & Biochem	0.20	0.80	0.00	1.00	0.18	0.82
Neurobiology	0.33	0.67	0.00	1.00	0.10	0.90
Neurology	0.13	0.87	0.17	0.83	0.00	1.00

Neurosurgery	0.25	0.75	0.40	0.60	0.20	0.80
Ob/Gyn	0.70	0.30	0.57	0.43	0.14	0.86
Ophthalmology	0.33	0.67	0.20	0.80	0.00	1.00
Orthopedics	0.33	0.67	0.00	1.00	0.14	0.86
Pathology	0.55	0.45	0.27	0.73	0.15	0.85
Pediatrics	0.43	0.57	0.53	0.47	0.24	0.76
Physiology	0.50	0.50	0.20	0.80	0.25	0.75
Psychiatry	0.52	0.48	0.43	0.58	0.21	0.79
Surgery	0.22	0.78	0.22	0.78	0.08	0.92
Overall	0.46	0.54	0.41	0.59	0.22	0.78

The overall percentage of females in all departments is 46% for assistant professors, 41% for associate professors, and 22% for full professors.

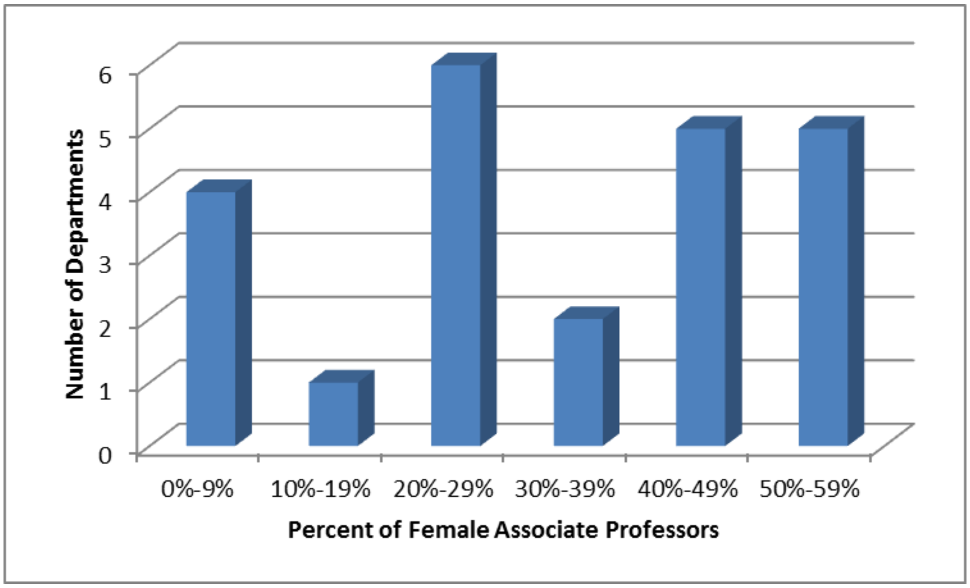
Not a single department has more females than males at the rank of full professors, even for those specialties that have more females faculty in the department, such as Pediatrics. Only one department has 50% female full professors (Emergency Medicine), zero have between 40% and 49% females, four have between 30% and 39% females (Dermatology, Public Health, Genetics, and Lab Medicine), eight between 20% and 29%, six between 10% and 19% females, and three between 0% and 9%. Two of the latter have 0% females as full professors, including Neurology and Ophthalmology. This distribution is similar to a bell curve (see Figure 8).

Figure 8 Number of departments in each 10% increment of Percentage of female full professors



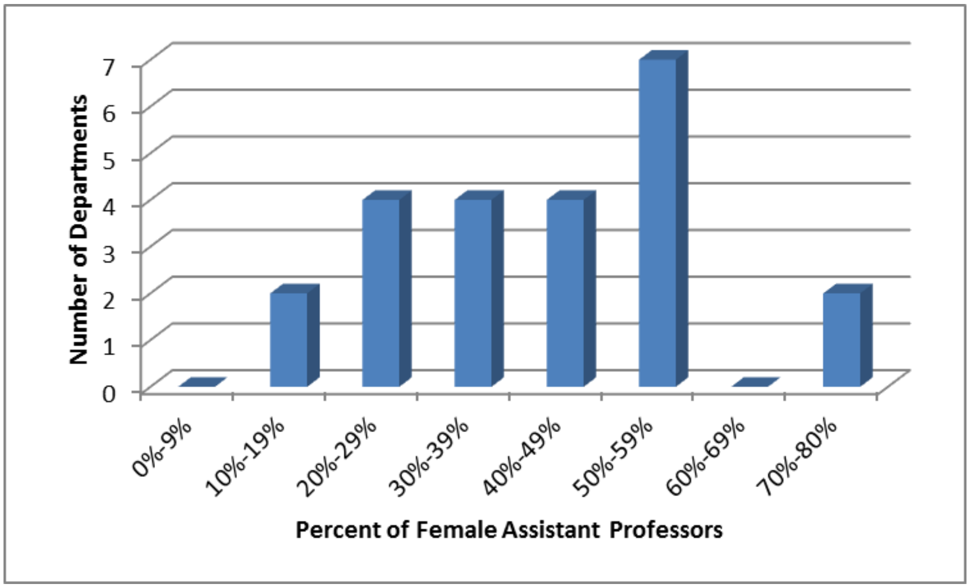
The disparity between females and males is lower at the associate professor level and assistant professor level (see Figure 9). For associate professors, females represent the majority in five departments (Emergency Medicine, Public Health, Genetics, Obstetrics/ Gynecology, and Pediatrics). Four departments (Dermatology, Internal Medicine, Neurosurgery, and Psychiatry) were into the 40%-49% range at the rank of associate professors. The other departments were below 40% females, including four departments that had 0 female associate professors (Cell Biology, Molecular Biophysics & Biochemistry, Neurobiology, and Orthopedics).

Figure 9 Number of departments in each 10% increment of percentage of female associate professors



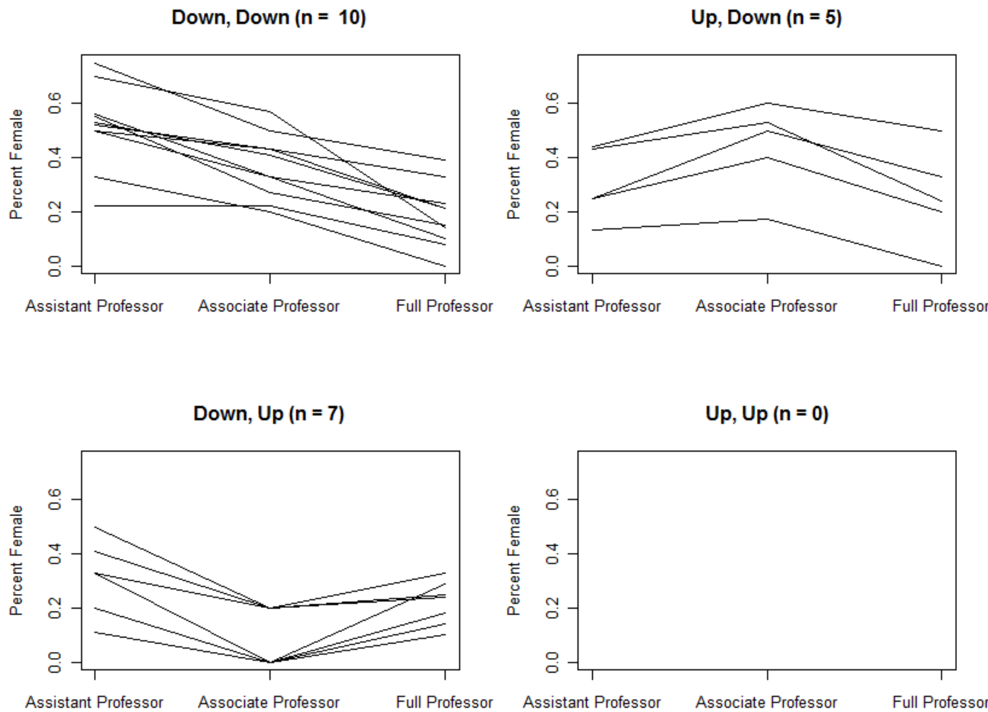
Assistant professors represented the rank with the highest number of departments having majority females (see Figure 10). Nine departments had greater than 50% females, with two departments at 75% and 70% (Epidemiology/Public Health and Obstetrics/Gynecology, respectively). Only two departments had less than 20% females, including Cell Biology at 11% and Neurology at 13%. The remaining departments were ranged between 20% and 50%.

Figure 10 Number of departments in each 10% increment of percentage of female assistant professors



The departments were then plotted according to their pattern of female representation as one moves along the faculty tracks (see Figure 11).

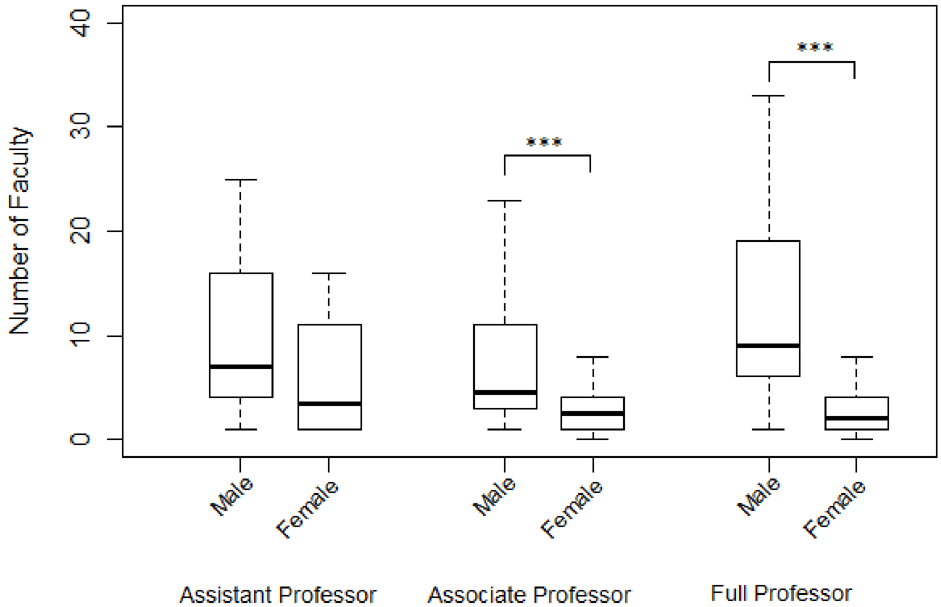
Figure 11 Each department, graphed by pattern of percentage at each level of faculty ladder



There are 10 departments that go down in representation from assistant to associate and then down again from associate to full professors. This is the most common pattern among the departments. There are five departments that go up in female representation from assistant to associate professors and then down from associate to full professor, including Emergency Medicine, Genetics, Neurology, Pediatrics, and Surgery. There are seven departments that go down in female representation from assistant to associate professors and then up from associate to full professor Cell Biology, Diagnostic Radiology, Lab Medicine, Molecular Biophysics & Biochemistry, Neurobiology, Orthopedics, and Physiology. There were zero departments that follow the pattern of increasing in female representation from assistant to associate professor and then from associate to full professor (up, up).

Using the faculty numbers in each department, a box and whisker plot is constructed (see Figure 12). In this plot, the median (solid line), 25^{th} and 75^{th} percentiles (box), and full range (whiskers) are shown for each gender at each level.

Figure 12 Box and whisker plot of number of faculty at each level of faculty ladder

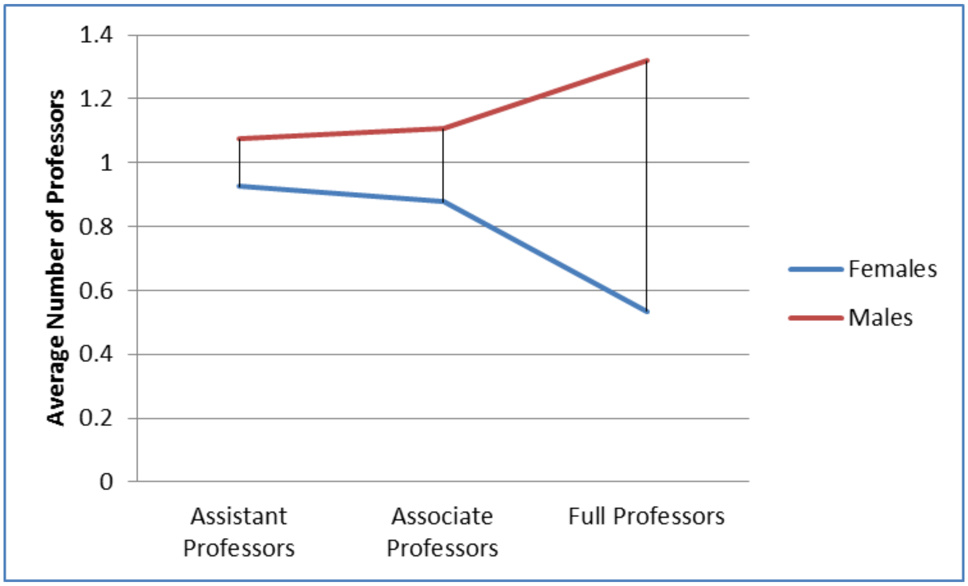


*** $p < 0.001$

The median for females is less than the median for males at each level, and the p-value for this comparison is less than 0.001 for both associate and full professors. The range of male full professors is the greatest. The plots for female faculty progressively decreases as one moves along the faculty track from assistant to associate to full professor, with a much greater change in the first step than in the second.

Using the average number of faculty in each department as one moves along the ladder faculty, a plot is constructed to compare them at each level (see Figure 13).

Figure 13 Average number of professors over departments at each level of faculty ladder



The gender disparity increases as one of moves from assistant to associate to full professor. The disparity between full professor males and full professor females is five times that of the assistant professor level.

Relative Rate Index Results

Using the same data set from the percentage calculations, the RRI was calculated for the 22 departments, individually and overall (see Table 4). The total sample size was N = 1305.

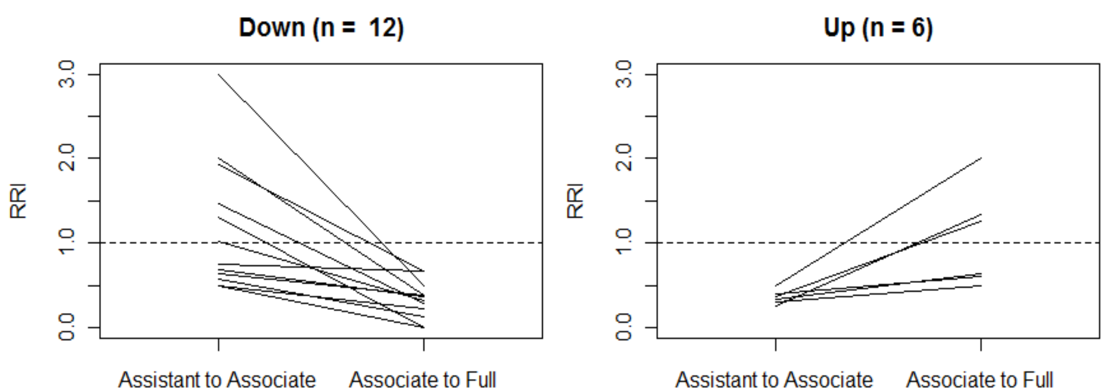
Table 4 Relative Rate Index matrix by department

Departments	Assistant to Associate Professor	Associate to Full Professor
Anesthesiology	0.40	0.60
Cell Biology	0.00	Undefined
Dermatology	0.75	0.67
Diagnostic Radiology	0.36	1.26
Emergency Med	1.93	0.67

Epid/Public Health	0.33	0.64
Genetics	3.00	0.50
Immunobiology	0.50	0.22
Internal Medicine	0.63	0.38
Lab Med	0.50	2.00
Mol Biophys & Biochem	0.00	Undefined
Neurobiology	0.00	Undefined
Neurology	1.30	0.00
Neurosurgery	2.00	0.38
Ob/Gyn	0.57	0.13
Ophthalmology	0.50	0.00
Orthopedics	0.00	Undefined
Pathology	0.30	0.49
Pediatrics	1.46	0.28
Physiology	0.25	1.33
Psychiatry	0.68	0.37
Surgery	1.02	0.32
Overall	0.79	0.40

The overall RRI of the study, or the relative rate of females progressing from one rank to another compared to their male counterparts, is 0.79 for assistant to associate professors, and 0.40 for associate to full professors (see Table 2). Four departments, Cell Biology, Molecular Biophysics and Biochemistry, Neurobiology, and Orthopedics did not have any female associate professors, so the calculation for RRI for associate to full professor level was not calculable. Of the remaining 18 departments, 15 have an RRI less than 1 for the associate to full professor level and three (Diagnostic Radiology, Lab Medicine, and Physiology) have an RRI greater than 1. The RRI of associate to full professors was higher than that of assistant to associate professors in six departments, including the three with RRIs above 1 from associate to full professors (see Figure 14). Those three departments include Diagnostic Radiology, Lab Medicine, and Physiology. The remaining three departments also have an increasing RRI from the first step to the second but they are both still < 1, including Anesthesiology, Epidemiology/Public Health, and Pathology. Of the 12 with higher RRIs in assistant to associate professors than from associate to full professor, five have RRIs above 1, including Emergency Medicine, Genetics, Neurology, Neurosurgery, and Pediatrics. Two departments, Ophthalmology and Neurology, have an RRI of zero from associate to full professor. For those departments, the RRI of assistant to associate professors is 0.50 for Ophthalmology and 1.30 for Neurology.

Figure 14 Each department, graphed by pattern of RRI at each change in level of faculty ladder.



Linear model results

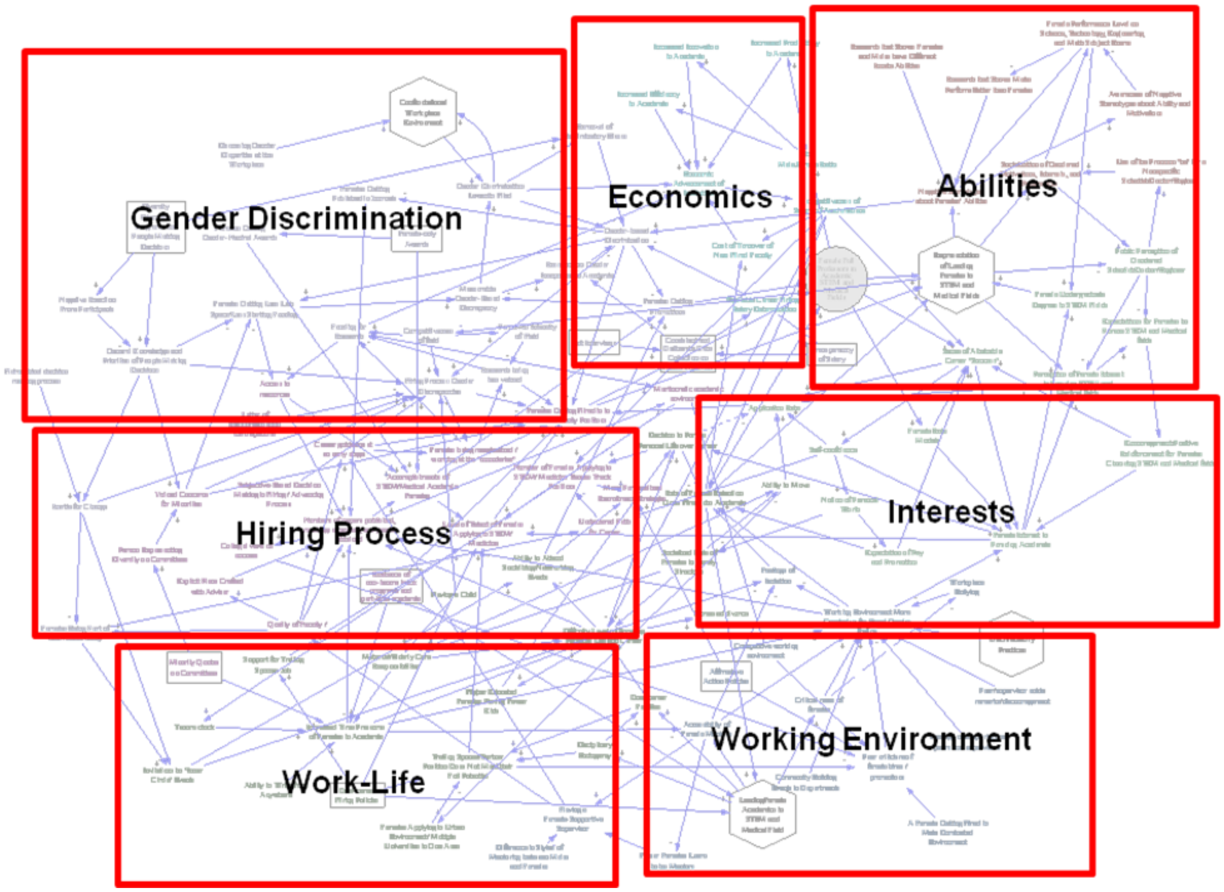
Using studies found in literature, five linear models were identified to compare to the SD Model in this study:

- A UCSF study found that increased mentoring leads to increased junior faculty performance for grant writing and general awareness about ladder tracks and tenure.[22]
- A New England Journal of Medicine Editorial reported on studies that being a female led to less lab space, lower grant support, and lower salaries, and reported having fewer mentoring relationships or less effective mentoring relationships than males. They also reported that, after 11 years, 5% of females working the same number of hours and having the same number of publications as their male counterparts received tenure from this group compared to 23% of males.[3]
- In 2008, Handelsman looked at how subconscious gender bias leads to lower rates of females being rewarded for the same amount of work as males in terms of scientific awards, publications, hiring and promoting.[28]
- Tower found that, for females, having a career will decrease numbers of children, increase divorce rate, and yet maintain the majority of housework responsibilities more so than their male counterparts.[23]
- A prospective study demonstrated that, for female physicians, having a family will increase the likelihood of working part-time and having less ambitious career goals.[39]

System Dynamics Results

Using an in-depth content analysis of over 50 articles, reports, and books published on this topic, two group meetings, and six interviews a system dynamics model is described. A total of 124 factors were determined to impact the hiring, advancement, and retention of females in academic STEM and medical fields. These 124 factors generated 32,766 loops. The model was divided into seven smaller constructs for ease of interpretation. Constructs define a theme for a specific model section (see Figure 15).

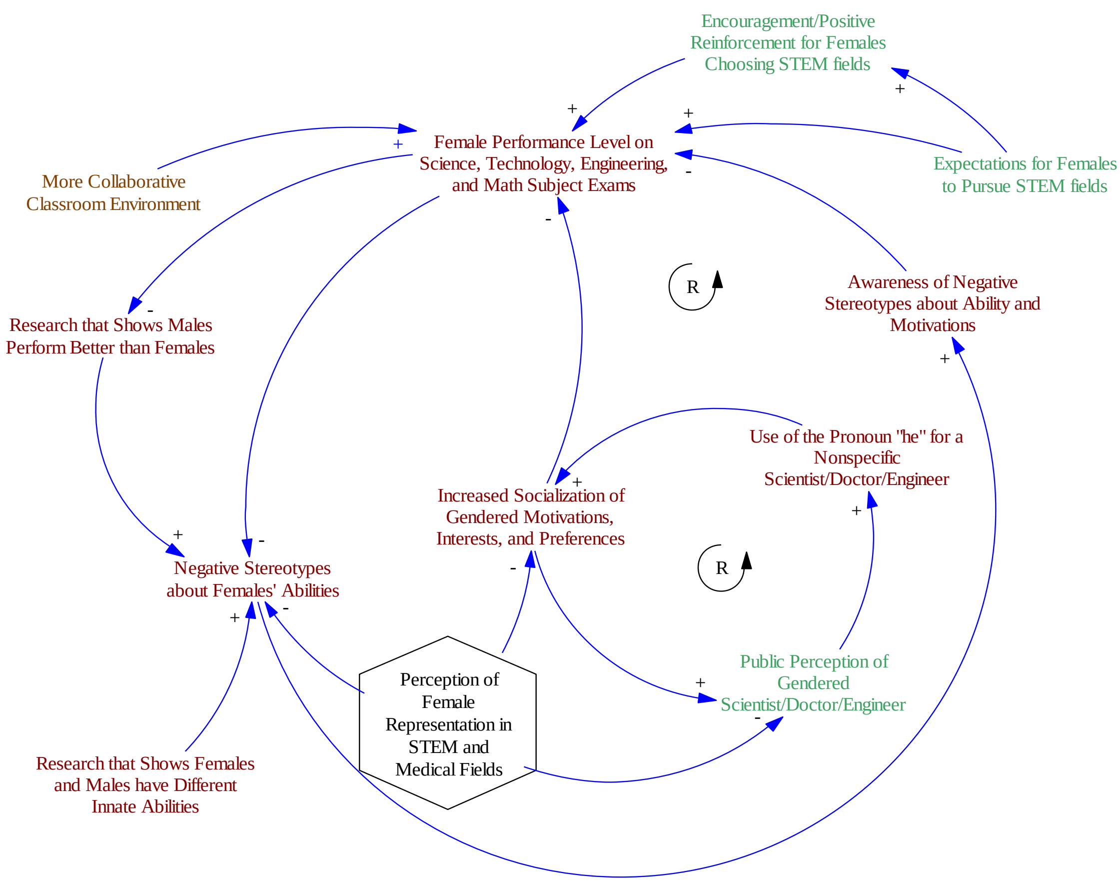
Figure 15 System dynamics model divided in to seven constructs.



The seven constructs include (in clockwise order starting from top right):

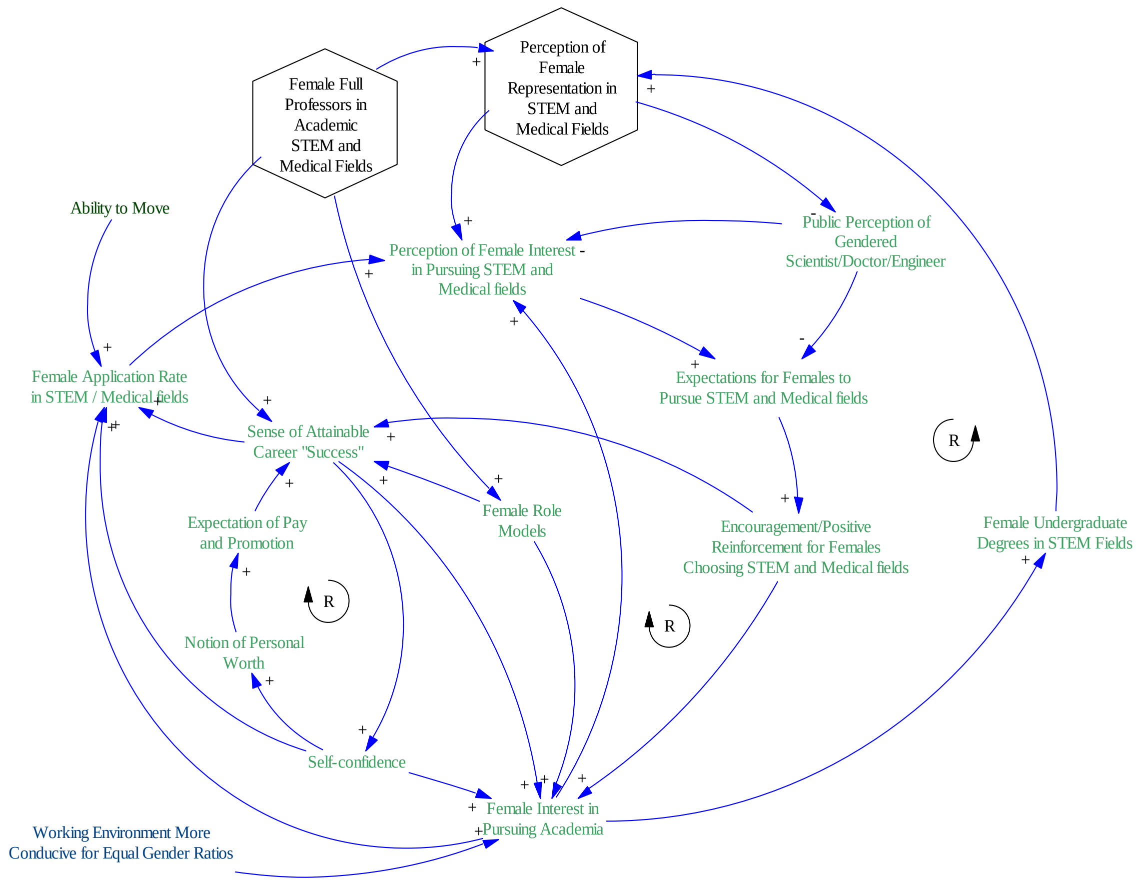
- Abilities – In the Abilities construct, research that portrays female skills and characteristics as inferior to males leads to negative stereotypes about females' abilities, which results in less confidence and poorer performance on STEM field testing. Poorer performance supports false research that shows female abilities are inferior to males, creating a reinforcing loop. Factors that enhance female performance include encouragement and expectations to pursue STEM fields. Using the pronoun "he" to describe the generic scientist or doctor and the socialization of females and males towards different standards, careers, interests, and preferences are also part of this sub-section that contribute to the reinforcing loop. Two factors that improve female performance on STEM field testing are encouragement and expectation to pursue and excel in STEM fields.

Figure 16 Abilities construct. The hexagon represents a factor that is represented in most or all of the constructs. Two reinforcing loops are present and indicated with counterclockwise arrows and an "R" inside. Factors that are primarily part of other constructs are present in a different color.



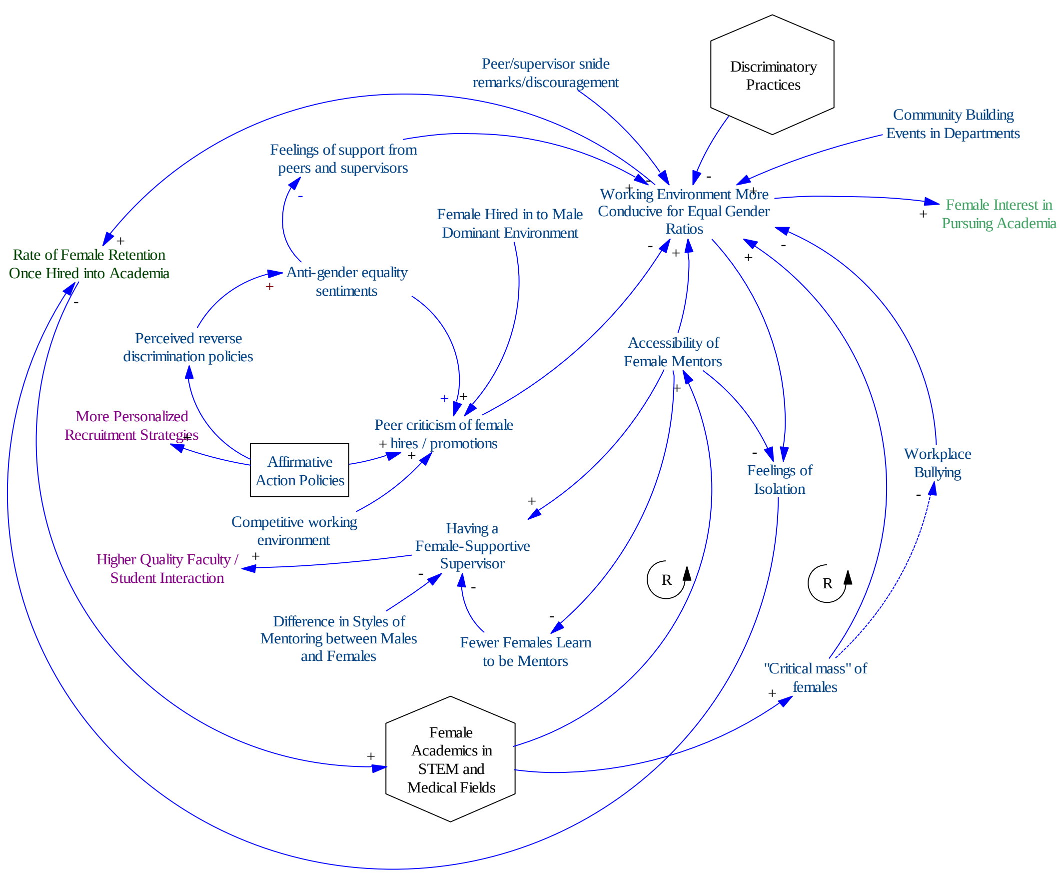
- Interests – The Interests construct is descriptive of societal perceptions of female interests in pursuing STEM fields leading to a decrease in encouragement and positive reinforcement for females to pursue STEM subjects, which leads to a decrease in their interest level. A decrease in their interest level not only decreases the number of females pursuing STEM fields, but also contributes to the gender-based societal perceptions regarding academia. More females are earning degrees in STEM fields at the undergraduate level than males. This, in addition to a decrease in female representation in STEM and medical fields, challenges the reinforcing loop that is created by societal perceptions and adds a balancing component. Finally, the availability of mentors, increased self-confidence, sense of attainable career “success,” and notion of personal worth are all factors that are modified by changes in the representation of females in leading roles in STEM and Medical disciplines.

Figure 17 Interests construct. The hexagons represent factors that are represented in most or all of the constructs. Three reinforcing loops are present and indicated with two clockwise and one counterclockwise arrows and an “R” inside. Factors that are primarily part of other constructs are present in a different color.



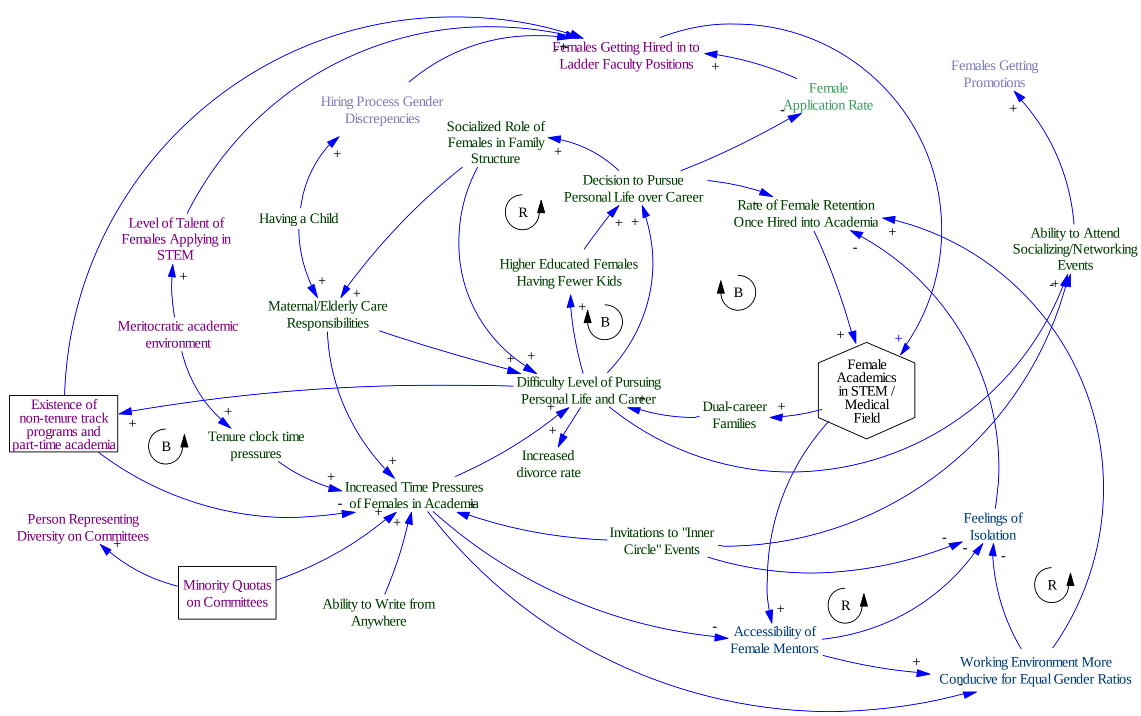
- Working Environment – The Working Environment construct describes a series of positive and negative interactions that happen in the workplace that contribute to the general working environment for females. A positive workplace environment leads to a higher retention of females, decreased feelings of isolation, and increased interest in females pursuing STEM fields. Some of the positive factors include feelings of support, critical mass of females, and community building events, while some of the negative factors include snide remarks from peers and supervisors, workplace bullying, sexual harassment, discriminatory practices, and peer criticism of female hires and promotions. Affirmative action has a role in this construct as well. Affirmative action leads to feelings of reverse discrimination, which leads to anti-gender equity sentiment, which leads to both an increase in peer criticism for female hires and a decrease in feelings of support from peers and supervisors. Both of these contribute to a negative workplace environment for females.

Figure 18 Working environment construct. Hexagons represent a factor that is represented in most or all of the constructs. A box represents an intervention and has the understood input factor of decreased females in academia. Two reinforcing loops are present and indicated with counterclockwise arrows and an “R” inside. Factors that are primarily part of other constructs are present in a different color. The dashed line represents a relationship that is positive at certain values of the factor prior and negative at other values of the factor prior.



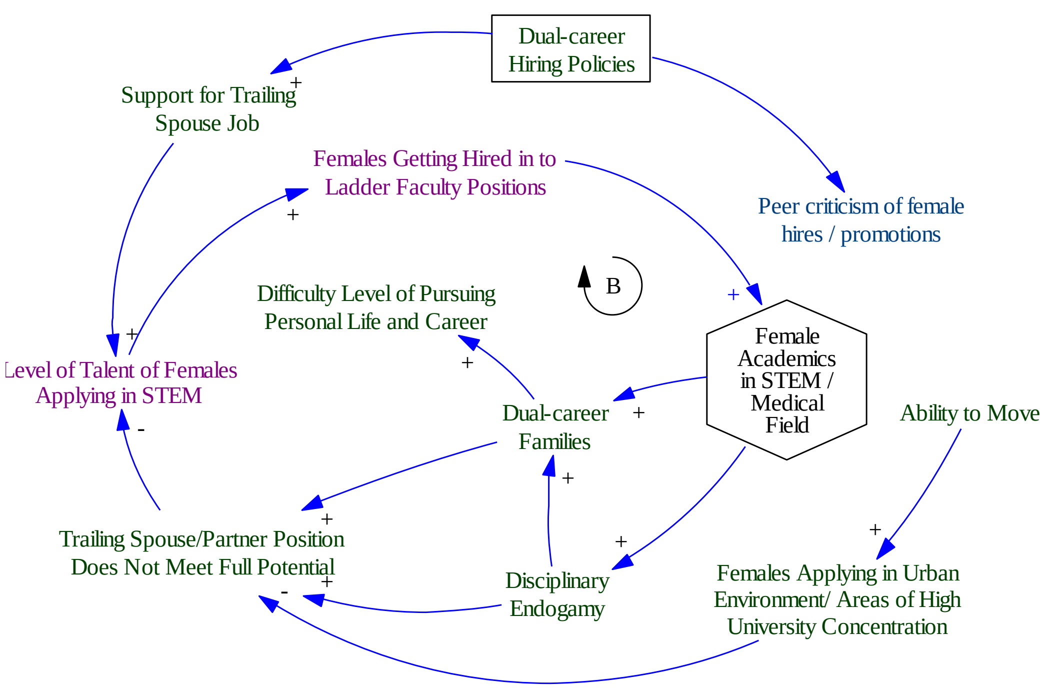
- Work-life – The Work-life loop describes a construct that includes factors such as lifestyle, family care responsibilities, and disciplinary endogamy. The socialized role of the female as the primary care-taker leads to increased time-pressures on females in the work-place, which leads to increased difficulty pursuing both work and life goals, which leads to more females choosing not to pursue academic careers. It also describes the nature of the academic career for its demands on time, including some interventions to increase female representation in academia and how they might have affected those demands on time negatively.

Figure 19 Work-life construct. A hexagon represents a factor that is represented in most or all of the constructs. Boxes represent an intervention and have the understood input factor of decreased females in academia. Several reinforcing and balancing loops are present with an "R" or "B" inside. Factors that are primarily part of other constructs are present in a different color.



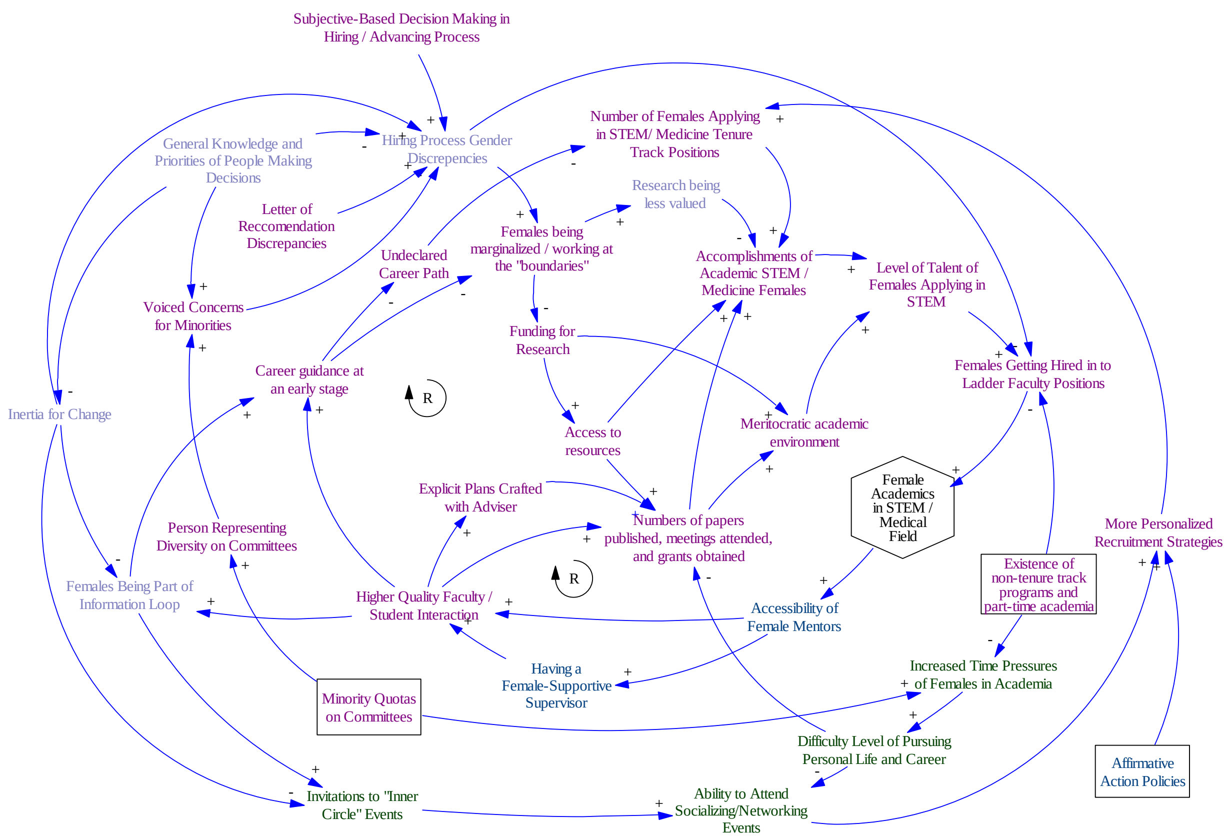
The remaining part of this construct is the trailing spouse section. In this section, dual-career families, where both spouses are a part of the academic system, experience difficulty finding faculty positions that meet the full potential of both spouses at the same university. Since females have a much higher rate of being in a dual-career family in which both partners are academicians, this system affects female academicians at a much higher rate than male academicians. Thus, this factor reduces the rate of females entering ladder faculty positions and leads to a decrease in female academics. Dual-career hiring policies and the ability to move, modify the system to try to decrease this effect of trailing spouses not obtaining a job that meets their full academic potential.

Figure 20 Trailing spouse section of Work-Life construct. A hexagon represents a factor that is represented in most or all of the constructs. A box represents an intervention and has the understood input factor of decreased females in academia. The balancing loop is shown with a clockwise arrow and a "B" inside. Factors that are primarily part of other constructs are present in a different color.



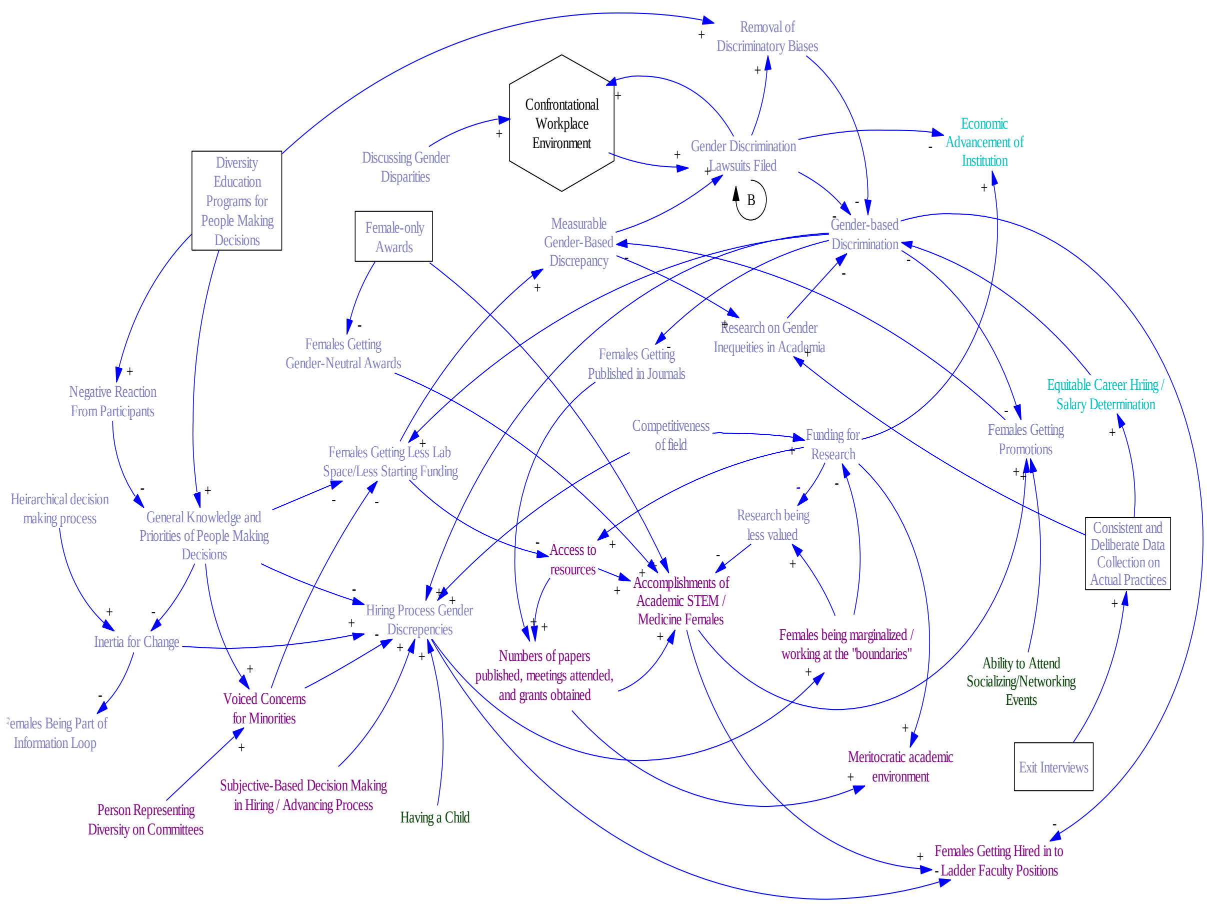
- Hiring Process – The Hiring Process construct brings in the processes of both hiring and promotion to the model. The factors related to this process include numbers of papers published, quality of those journals, numbers of grants awarded, types of grants awarded, grant mechanisms, and goals of the hiring committee. Those factors are positively increased when the student-faculty/ mentor relationship is strong and when the hiring committee has objective criteria or a process that strives to eliminate inherent biases. An increase in diversity education of the people on the committee, diverse committee representation, specific plans for career progression, and decrease in discriminatory practices are factors that when increased, lead to an increase in females being hired and promoted into academia. Another aspect of the academic system that is part of this sub-section is that of networking. Networking leads to being knowledgeable about inner circles, which leads to increased chances of being hired/ promoted.

Figure 21 Hiring construct. A hexagon represents a factor that is represented in most or all of the constructs. Boxes represent an intervention and have the understood input factor of decreased females in academia. Two reinforcing loops are shown with a clockwise arrow and an “R” inside. Factors that are primarily part of other constructs are present in a different color.



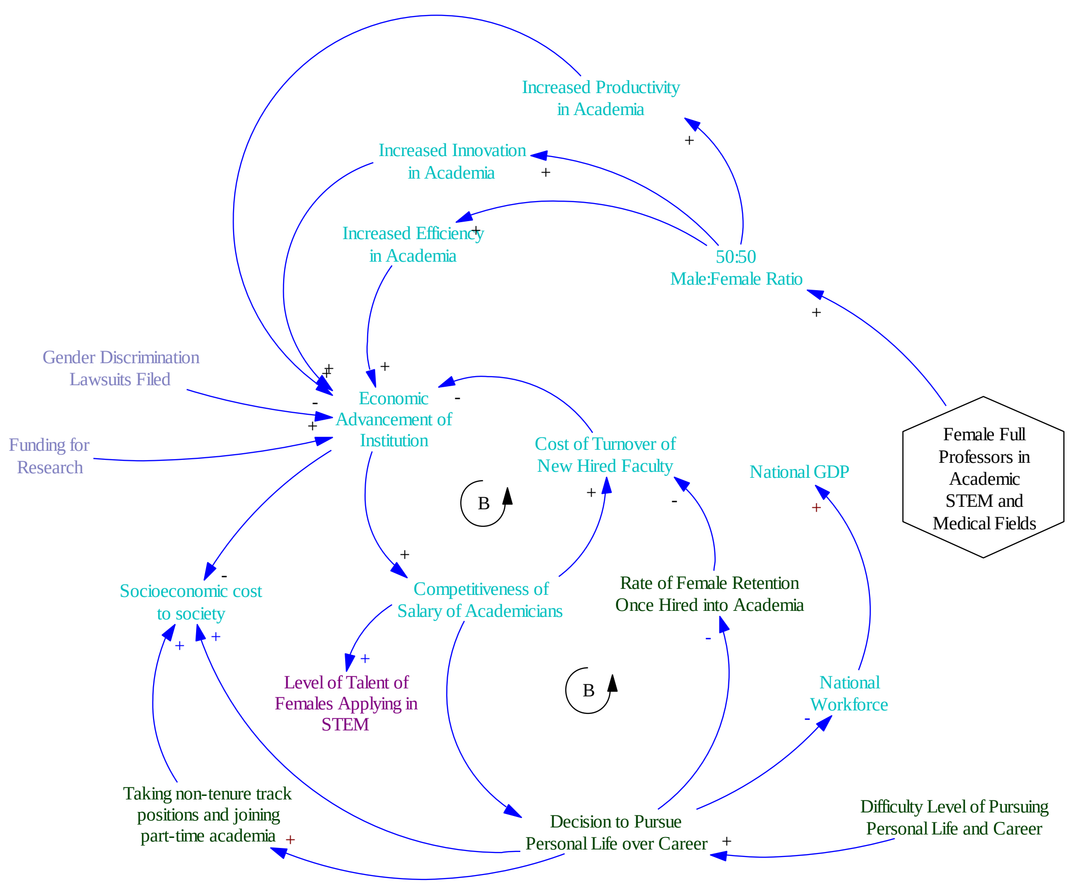
- Gender Discrimination - The Gender Discrimination sub-section describes gender-based discrepancies in the academic workplace and their upstream associations and downstream effects. Discrimination, such as discrepancies in allotted lab space, access to resources, starting salaries, and startup funding, puts females at a disadvantage in publishing and earning accolades. Overt discrimination that is more confrontational leads to a more negative environment in the workplace. Efforts to impede discrimination through confrontation or legal action also lead to a more hostile workplace environment. There are several interventions that have been put into place that contribute to decreased discrimination that can be seen in this sub-section. One such intervention is deliberate data collection, which leads to knowledge of discrepancies that resulted from inherent gender biases. Other interventions include female-only awards, transparency, and a minority representative on committees.

Figure 22 Gender discrimination construct. A hexagon represents a factor that is represented in most or all of the constructs. Boxes represent an intervention and have the understood input factor of decreased females in academia. The balancing loop is shown with a clockwise arrow and a "B" inside. Factors that are primarily part of other constructs are present in a different color.



- Economics – In several different ways, this construct indicates that decreased retention and decreased ratio of females below 50% generates economic losses for the university, academic community, and the nation. An increase in female representation to 50:50 leads to increased innovation, efficiency, and productivity in the workplace. Also, increased retention saves hundreds of thousands of university dollars spent on recruitment and training of new faculty and also has implications for the working environment. Finally, factors that may cause educated females to leave the scientific workforce also leads to increased socioeconomic costs to society. Along those lines, a decrease in females in the national workforce also leads to a decrease in national GDP.

Figure 23 Economics construct. A hexagon represents a factor that is represented in most or all of the constructs. Two balancing loops are shown with a clockwise arrow and a “B” inside. Factors that are primarily part of other constructs are present in a different color.



Section 5 Discussion

Percentages vs. Relative Rate Index

In trying to measure the status of current progression of females through the tenure track in academic medicine, one can compare the effectiveness of percentages to RRI. Overall, percentages indicate that females are most underrepresented at the full professor level at just 22%, almost half of assistant (46%) and associate (41%) professor levels (Table 3). Distribution of the departments according to their percentages shows that the full professor level has the least evenly distributed graph (Figures 8 – 10). Charting each of the department's faculty numbers per level in a box and whisker plot shows that the greatest difference between the medians of males and females is also at the full professor level ($p < 0.0001$, Figure 12). The graph of average departmental faculty numbers for each level also indicates that the gap between males and females is largest by far in the full professor level (Figure 13). These aggregate analyses all indicate that the full professor level is the level at which there is the worst underrepresentation of females, and thus, conclusions are often drawn that that should be the level of focus for further analysis of the issues that go in to hiring and promotion and also of interventions.

However, on further examination of the box and whisker plot, one can see that the plot for female associate professors and full professors appear very similar in size and distribution, whereas there is a much larger drop from female to associate professor. This clues to the idea that females may not be progressing from one stage to the next at an earlier level than what percentages calculated. In fact, Figure 11 actually shows that there are seven departments that have a higher representation of females in the full professor level than in the associate professor level, indicating that from assistant to the associate professor level is where those departments have a lack of female advancement. Additionally, there are two departments, Emergency Medicine and Genetics, which actually have their lowest representation at the assistant professor level. Thus, graphing the departmental percentages helped identify nine departments in which percentages are lowest in a level other than full professor, seven of which are in the associate professor level. It does not give any information about whether the female representation at any level is more or less than what one could expect given the representation in the stage prior.

To compare with percentages, an RRI analysis shows RRI for the majority of departments is less than 1, which means that fewer females are advancing to a subsequent level given the number of females in the previous rank relative to males. Twelve departments have lower RRIs at the rank of associate promoting to full professor than assistant promoting to associate professors, which means that females have a lower rate of progression from associate to full professor per male than they do from assistant to associate professor in those departments. Six departments have higher RRIs for associate promoting to full professor than assistant promoting to associate professor, meaning that those departments actually do better at advancing females from associate to full professor than they do at advancing females from assistant to associate professors. In addition, four departments have an undefined RRI at the associate to full professor level. These four departments have an RRI of 0 for the assistant to associate professor level and are the four departments that have zero female associate professors and a non-zero number of female full professors, which means they also do a better job of promoting to full professor than they do of promoting from assistant to associate professor.

Thus, using RRI, a total of ten departments were identified that do a better job of promoting females from associate to full professor level than they do from assistant to associate professor level. The percentage analysis only identified seven departments that showed associate professor to be the most lacking in female representation. Those seven are all part of the ten identified by RRI. The additional three are Anesthesiology, Epidemiology/Public Health, and Pathology. These three departments show a decreasing trend in percentages as they move along the faculty ladder (see Table 3), but the decrease from associate to full professor is less than the decrease in assistant to associate professor. This critical information is eliminated when solely relying on percentages but is easily identified with RRIs. Thus, the hypothesis that RRIs are superior to percentages to identify and measure underrepresentation of females in the ladder faculty track, is supported. RRIs are better to determine where and how much females are underrepresented relative to males in the context of the entire system.

Just as the actual numbers of faculty has informational value in knowledge of the population size, percentages also have informational value in offering the relative representation of one gender with respect to the other. For example, percentages show that all departments except one (Emergency Medicine) have a lower percent of females in full professorship than males. Emergency Medicine is 50% female full professor. Tables 9 and 10 indicates that there is a more even distribution among associate professors in nine departments with the proportion of females at 40% and 60% . Ten departments are relatively equal at the assistant professor level with a female proportion between 40% and 60%. At the same time, percentages offer a different perspective than RRI that would often lead one to draw opposite conclusions from what the analysis indicates. For example, the three departments that show an RRI > 1 for associate professor to full professor include Lab Medicine at 2.0, Diagnostic Radiology at 1.26, and Physiology at 1.33. However their percentages are 33%, 24%, and 25% females at the full professor level, respectively. If only relying on percentages, one might conclude that those departments are not doing as well as they are at promoting females to full professorship. However, per female represented in the prior level, they are promoting a greater number relative to the number of males promoted per male from the prior level. Thus, percentages do not adequately provide information on promotion from one level to the next, while RRI offers that information accurately and concisely.

Further RRI Interpretation

The information gained from RRI can be used to target steps of the ladder faculty that show the lowest rate of progression from one stage to the next. The overall RRI is lowest for full professors at 0.40, compared to 0.79 for associate professors. Considering that 1.0 represents equality, these values indicate that the stage of transition from associate professor to full professor may be the most gender biased. The extent to which this is true is limited by the fact that full professors include many older tenured professors that went through the tenure track during the time period when very few females were trained or worked in academia. Thus, newer female and male full professors may be entering at an equal rate with respect to the level of female and male associate professors. However, the percentage of full professors remains disproportionately high, while it includes the older males and this will be subsequently reflected in a part of the RRI calculation as well. The RRIs of full professors reflects a lower percentage for females and higher percentage for males than what would otherwise be calculated if the older professors were not included in the count of full professors. A better calculation of progression through the tenure system would remove all males and females that were tenured before a certain year.

The overall RRI for assistant to associate professor is also less than 1, indicating that fewer females are advancing per female assistant professor than males are advancing per male assistant professor. This is important because it indicates that gender bias is occurring at the level of promotion from assistant to associate professor as well. Gender discrepancies at this level are not often discussed in the literature, if at all. This is because the most drastic percentage difference is at the full professor level. In practice, however, there are ten departments that demonstrate through an RRI analysis a higher progression of females from associate to full professor level than assistant to associate professor level, which means that the level that many females do not achieve in promotion is actually to associate professor.

The reasons for this discrepancy are many and vary from department to department. Though not directly related to comparison between RRI and percentages, one of the reasons that females may not be progressing to the associate professor level is that they decide not to pursue promotion and retain a non-ladder faculty position rather than not receive promotion and be asked to leave the university. In some departments, appointment to assistant professor is readily given but guidance towards achieving promotion to associate professor is not provided uniformly and systematically. Faculty who are within the right information networks are provided the most opportunity to excel and succeed in promotion to associate professorship. Faculty who are not promoted are subsequently asked to leave their university within one year. For this reason, faculty who may not anticipate being promoted may decide not to enter promotion for associate professorship altogether, especially if they received no guidance about how to improve their chances of obtaining it. Females are the more disadvantaged in this system since they are more excluded from informal information networks that guide assistant professors towards successful promotion. The idea of a systemic effect that limits the progression of females to the associate professor level taking place at the associate professor level only comes from the ability to identify a significant lack of progression to the associate professor level in females relative to males using RRI. A lack of focus on where females are actually falling out of the ladder tracks leads to oversight of important conclusions that can be drawn and limits the implementation of effective interventions to improve the system.

Future Direction

More directions can be taken with the RRI analysis that would enhance the understanding of female underrepresentation in the faculty ladder. First, one can calculate the RRI of averages over a period of time (3 – 5 year increments) and calculate a more robust RRI that eliminates large scale variations seen when working with small populations such as the academic medicine departmental faculty population data. Second, a temporal analysis of RRI can be used to determine trends over time and measure the effects of any interventions that were introduced during that time period that might have affected it. Third, one could consider using purely applicant and accepted applicant data. For example, instead of using numbers of each gender in each rank, one would use the numbers each gender for accepted candidates among the available applicants to calculate the RRI. This calculation is helpful because promotion to the next level is not always internal and many faculty are hired in to the upper faculty ranks from other universities. One important note, however, is that applicant data can also be skewed towards a certain gender based on likelihood to apply. A fourth analysis to be done is to recognize the departments that are doing better or worse than the others and analyze their policies and practices in hiring, promotion, and retention of females for similarities and differences among them. Though all of these analyses would give accurate institutional data, the numbers for a single university may also be considered to be too small for making any relevant inferences about a department, even if using averages or trends. Thus, a fifth analysis that can be done is a multi-university RRI calculation if the universities were fairly similar in their applicant pools and hiring rates.

Linear Model vs. System Dynamics

The results from the content analysis of existing research identified a spectrum of factors related to the underrepresentation of females and indicate a cause and effect relationship among them. The analysis of these factors offers logical evidence for the relationships observed; however, they lack in a comprehensive perspective on the issue. For example, two of the studies demonstrate that being a female leads to consequences in access to resources and promotion to full professor. While this may be accurate, there are several steps between that cause and effect that can assist in explaining how being a female leads to those consequences, which are not part of the study. The same is true for the two studies that report careers decrease family size and families lead to less ambitious careers, both more so for female faculty than male faculty. This is effectively a recursive relationship that is described in two separate studies. Unfortunately, the methods of each study is restricted to a linear analysis between those two factors, when in fact, they have interdependent impacts on each other and share many co-dependent factors that are not part of either study. Research that allows for a more comprehensive analysis of those factors is needed. Handelsman's study does identify a root cause of inherent biases leading to decreased recognition for work for females more than males. However, the factors that lead to inherent biases and the subsequent effects of decreased recognition for work are not elucidated. A targeted intervention against inherent biases might easily have an effect on another related issue but that would not be predictable solely relying on the study results.

Linear, static models are not incorrect in their analysis, they are often just incomplete. To determine the underlying factors that restrict females from advancing in academia, system dynamics modeling provides critical information that is not available in static linear models. SD models demonstrate the recursive and dynamic relationships that are important to the overall model that linear models are unable to capture by their very nature. A thorough understanding of gender based discrepancies involved in the academic system has long eluded researchers because the research to date has been linear at best. There are many reasons why SD is a more suitable tool for evaluating gender disparities in academia. First, the system is complex with many factors that vary from institution to institution and city to city. Narrowing the scope and over-simplifying a study for ease of analysis limits the extent to which the root causes can be determined. Second, university departments operate independently in hiring and promoting such that the scale for studying this particular process and similar ones like it is often too small to make any statistically significant conclusions. Third, there are many factors not inherently quantifiable and yet are critical components of the overall social system. These factors require a qualitative approach for analysis to complement the quantitative analyses already discussed. At its core, qualitative research focuses on the meanings, traits, and defining characteristics of events, people, interactions, settings, cultures, and experience, which are all necessary to better understand gender disparities in academia. "Quality refers to the what, how, when, and where of a thing – its essence and ambience"(page 3).[62] For all of these issues, system dynamics modeling offers a suitable solution for analysis and understanding of the system. It is a modeling tool specifically for complex systems that represent non-linearity, which is more representative of the real world. In addition, it can incorporate factors that are difficult to quantify and be pictorially represented for ease of interpretation and assessment.

SD provides a method of in depth analysis of an issue that is simply not possible through the use of quantitative, statistically-based investigations that are linear and static. SD is an approach that centralizes all relevant factors and their inter-relationships and places primary value on their systemic effects, and how people understand, experience, and respond within milieus that are dynamic in their foundation and structure. These factors exist in any system that can introduce human bias, i.e. any system that involves human judgment and subsequent decision making. Their difficulty in quantification has made them more inclined to be left out of prior analyses of this issue; however, they are very important to the overall system dynamics. This SD model allows for a comprehensive, qualitative understanding of the social aspects of how female underrepresentation in STEM and medical academia occurs and how the factors affected by this underrepresentation operate in the context of the system in which it exists.

Downstream Effects of Interventions

Several interventions that have been instituted over the years have had downstream effects in other parts of the system that were unintended consequences. The interventions listed below are discussed for their positive and negative effects using a system dynamics lens.

Affirmative action policies are aimed at recruiting more females to apply for academic positions. Publicizing that a university has adopted affirmative action policies has had unintended negative consequences. Peers of female hires and female hires alike are less inclined to respect their faculty positions if they know that affirmative action policies were involved. They believe that the merit-based standards of the position were lowered in order to hire more females, and thus, the new hires are less competent than they would otherwise have been. One reason for this is that the explicit policies that are enacted are often nebulous to the general community. The peers of the new hires are not yet involved in such university wide decisions and so they do not know the exact mechanism of how the policies are put into practice. In many cases, affirmative action policies have been labeled as reverse discrimination and unethical. Another reason is that meritocracy has long been the culture of academia and every individual is looking out for themselves in the struggle for tenure or promotion. This environment creates conflict for individuals who theoretically have no gender biases however are put into an environment where there is cause to identify weaknesses in their peer competitors.

Minority representation on committees and search lists were interventions introduced to give both voice and opportunities to minorities in various committees. The idea that increased diversity would enhance innovative thinking played some role in this intervention. The negative consequences that were realized by the minorities were that their limited time became even more taxed with committee meetings and responsibilities. Each committee came with time commitments that took valuable time away from research and academic progress. The fewer females and minorities there are, the more these individuals are burdened than their white male counterparts to fulfill university requirements for diverse representation on committees. Second, females and minorities are often appointed to committees by virtue of their diversity not because of their understanding and advocacy for diversity issues. Someone who has had advanced training in its importance who is not a member of that minority community is often a better advocate. Policies are also often not executed according to their original intention. Search committees who populate a list of potential candidates have requirements to include a diverse set of individuals. The same individuals populate the search committee lists of several institutions to fill the diversity requirement, no matter how unlikely it may be for that female to leave her job for the proposed one. This practice represents an error in the way this intervention is implemented.

Female-only awards are meant to be another route for females to gain recognition and accomplishments. They are meant to supplement the normal selection of accolades possible for academic females; however they often take the place of them. Females who are selected for a female-only award are often not considered for the “equivalent” all-gender award, which is usually perceived as more prestigious. Thus female-only awards lead to a decrease in overall recognition for females, which is the opposite of the intended effect of this intervention. This represents a systematic flaw in the process that allows for further gender-based discrimination to occur.

Dual-career hiring policies is an aspect of the model that is under-researched and yet extremely important for females in academia. Dual-careers are more prevalent among academic females than academic males. Often, there is only one position available at a time, especially within a single discipline. In situations where both spouses are searching for an academic position, departments may be less inclined to offer the position to one if the other is not likely to be hired. This is because that candidate is less likely to take the position without their spouse also receiving a job offer, which would require significant inter-departmental negotiations that may prove costly for the department. The position that the “trailing spouse,” as it is termed, receives is often not at the level of the full potential that that person could have obtained elsewhere. The trailing spouse is often hired in the more marginal, non-ladder track positions with decreased advancement potential. This process is how the current system is naturally set up without specific policies that help ensure that both spouses are given a position that allows them to meet their full academic potential at a university. Often, couples may limit their careers to metropolitan areas so that they can reach their academic hiring potential at a wider selection of universities. Without specific dual-career hiring policies, the system disadvantages females at a disproportionally increased rate due to their increased likelihood to be a spouse of another academician. Male academicians are more likely to have homemaker spouses or a spouse that works outside of academia and are less affected by the “trailing spouse” problem.

Diversity education programs have been introduced to offer a perspective on the need for diversity in academia and to prevent discriminatory practices from occurring. There are various types of such programs, some are targeted towards the people making decisions but most are for the general population of academicians. These programs, no matter how interactive or engaging, are often seen as time-consuming and unnecessary by academicians, who are constantly under time pressures. Thus, they often lead to negative reactions or even backlashes that are either expressed or internally felt towards the topic of diversity. People are much less inclined to discuss these issues casually or bring up a situation that might be seen as controversial because it creates a defensive reaction in an already hostile environment surrounding this topic due to the mandated diversity education programs. Thus, these programs also limit the open environment for discussing diversity that they are meant to create and promote.

The aforementioned interventions are theoretically positive in intent from one perspective but downstream effects are not always so. They demonstrate the need for an intervention that is more systemic and comprehensive. One must invest resources in determining the goal of each policy and practice in the academic system and whether the way that policy and practice is carried out meets those goals sufficiently. Data collection and analysis can be combined with active change in policies and practices in order to give a more evolutionary process to systemic changes and thereby meet the overall goals of the academic system efficiently yet effectively.

Suggested areas for intervention and more research

Deliberate data collection with transparency is a necessary first hurdle that all universities must work hard to overcome in order to begin to make changes. Deliberate data collection gives quantifiable measures of the system and transparency helps to create an environment of collegiality instead of competition. Also, a policy of transparency allows for accountability by academic employees, who are otherwise in a much compromised position, with their employers. While publishing gender disparity indices may be embarrassing to university administrators, it is a necessary first step in resolving gender disparities. The following are ideas for what can be published for furthering the progressiveness of the universities:

- Relative rate index for each stage of ladder faculty track
- Salary averages, lab spaces, and starting salaries by gender
- Average advancement rates by gender and year of hire
- Average education and experience level of new hires by gender
- Dual-career applicant demographics and final resolution information
- Mentoring quality assessments

Exit interviews with retention interventions is the most basic way for information to be collected regarding what factors led to someone's decision to leave their academic position. This information is of most immediate economic value to the university since the loss of a person who has been recruited is a costly endeavor. Exit interviews should be conducted by members of the faculty who are widely trusted and regarded as being unbiased. Often, there is an appointed person whose role is to be unbiased, but many individuals feel that he or she is in fact very biased. Therefore, careful thought should go towards selection of the individual conducting exit interviews. Data should be collected anonymously and continuously. Feedback from these interviews should be provided to committees, chairpersons, and deans to ameliorate underrepresentation of females in academia.

Gender differences in mentoring, learning, teaching, working environment have been studied extensively, and their existence is well-established. The system of education and academia was developed for and by males, and females learn, teach, mentor, and respond to mentoring in a slightly different style largely due to a difference in the socialization of each gender in the U.S. culture. This difference must be addressed and new and enhanced mentoring, learning, and teaching methods and a more gender equal working environment. Advanced learning techniques based on collaboration have been established to be superior to those based on competition. Also, introducing more community building events into the workplace, and training mentors on female-specific mentoring techniques are important interventions for the evolving changes in the gender balance in academia.

Systematic career guidance at earliest stages of professorship offers more options to candidates who might be interested in academic careers. Guidance to pursue the activities that may lead junior faculty to become better candidates for promotion in the faculty ladder is critical and yet not systematically offered in academia. Without proper guidance, these activities remain elusive to junior faculty. The process of obtaining a proper mentor is completely subjective and not guaranteed. Senior faculty may choose to offer as little or as much help as they want to whomever they want. Thus there is ample room for bias to exist and play out. For example, senior faculty may feel most comfortable mentoring individuals who remind them most of themselves or of the people who they are already used to working with. This bias is very common and works most against females since the majority of the experienced faculty and mentors are males. A more systematic approach to mentoring that guarantees that all junior faculty will receive the same information and opportunities to succeed is imperative.

Other ideas for changes based on points of weakness in the system:

- Systematic change to making the next step more accessible in the promotion track.
- Redoing the tenure and promotion system so that appointment is not for life
- Team promotion policies
- Monetary incentives for gender equal departments

There are many ways in which the system dynamics model on female underrepresentation in academia can be furthered and expanded. First, conducting more working groups with representatives from even more universities than the two included in this study might offer additional perspectives on this issue. In addition, more robust modeling could be obtained from a system dynamics trained team of researchers than just one person. Another issue is that there is a balance between the complexities of information shown in the model versus the amount that is useful to portray for ease of interpretation. Because the focus of this model was to display the comprehensive system surrounding the issue of underrepresentation of females, factors were kept specific and separate rather than summarized and condensed. Condensing the factors may reveal relationships among parts of the model that have not yet been evident. Even still, more factors may be relevant that were not yet included. Additional research in the areas suggested above is necessary for a better understanding of the dynamics of this social system and subsequently plan more appropriate interventions. Lastly, quantitative data can be added to this SD model for further analysis. Both institutional records and survey data can be collected to enhance and test this SD model. Next steps will include incorporating the quantitative methods with this qualitative process to generate an even greater understanding of gender disparities in academia.

Section 6 References

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Section 7 Figure References and Legends

Figure 1 Science, Tehchnology, Engineering, and Math (STEM) doctorates awarded, 1996 - 2007

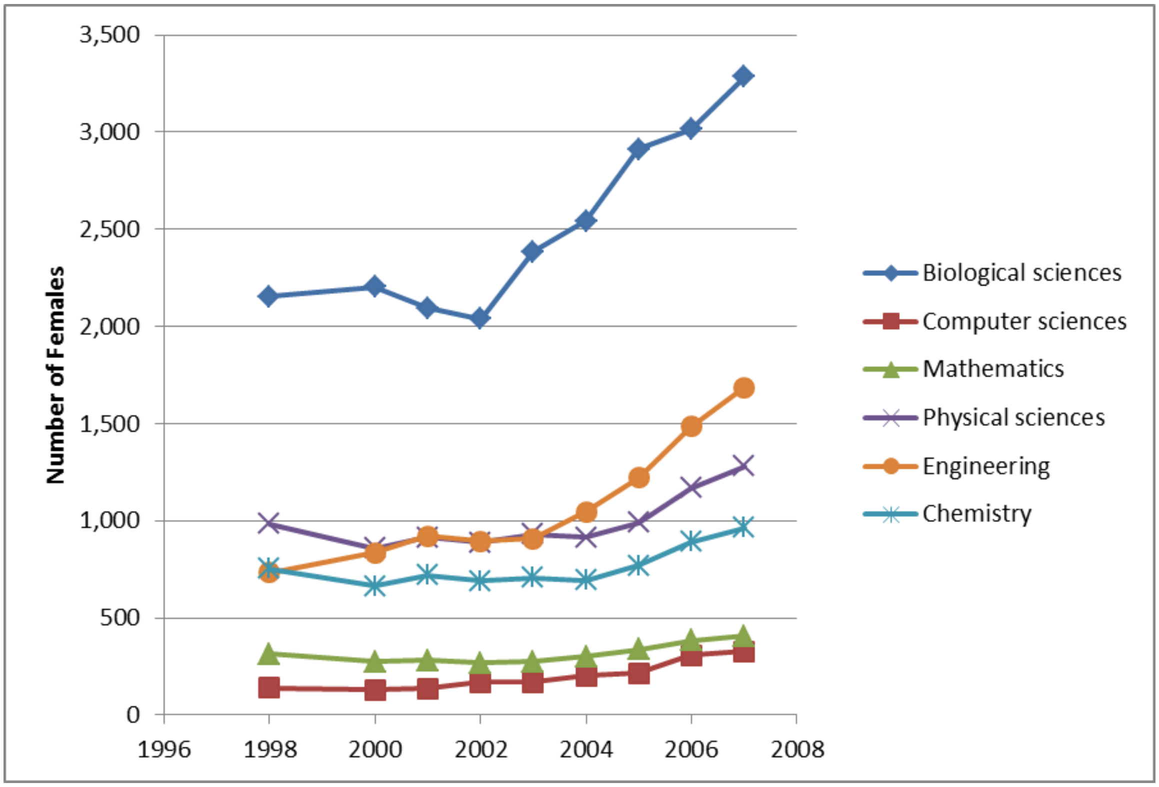


Figure 2 Percentage of females graduating from U.S. medical schools

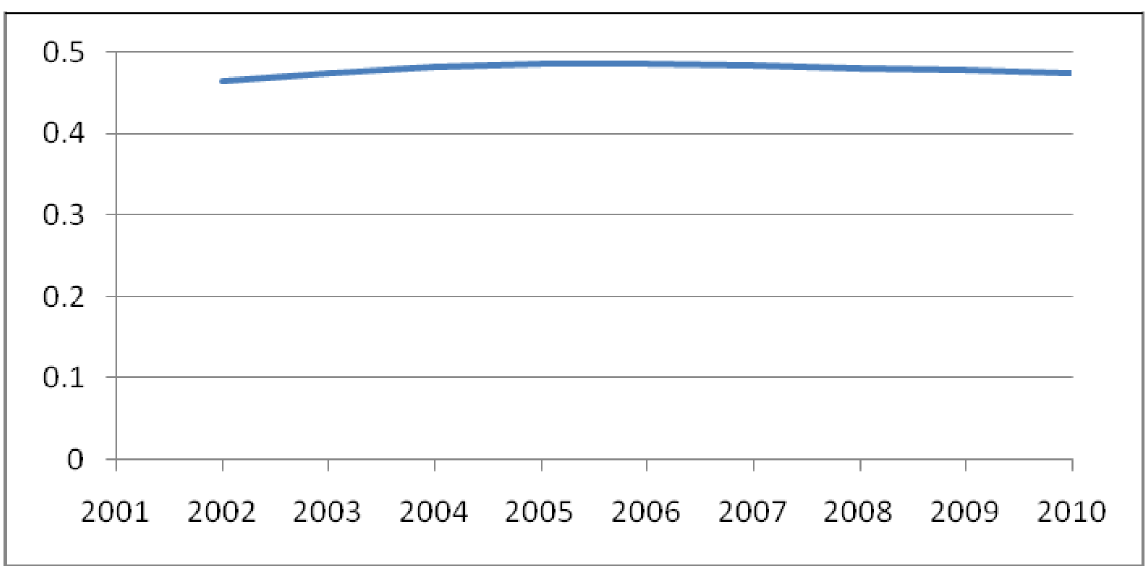


Figure 3 Science and engineering faculty position by years since doctorate, 2006

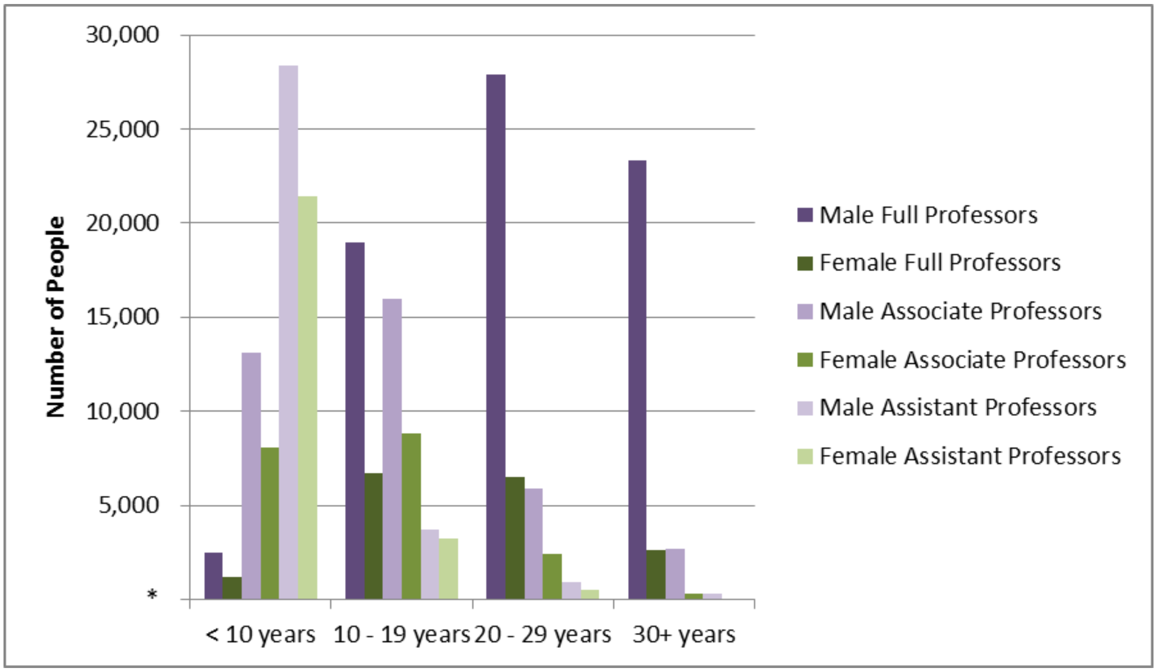


Figure 4 Advancement in academic and leadership positions relative to each gender, 2008

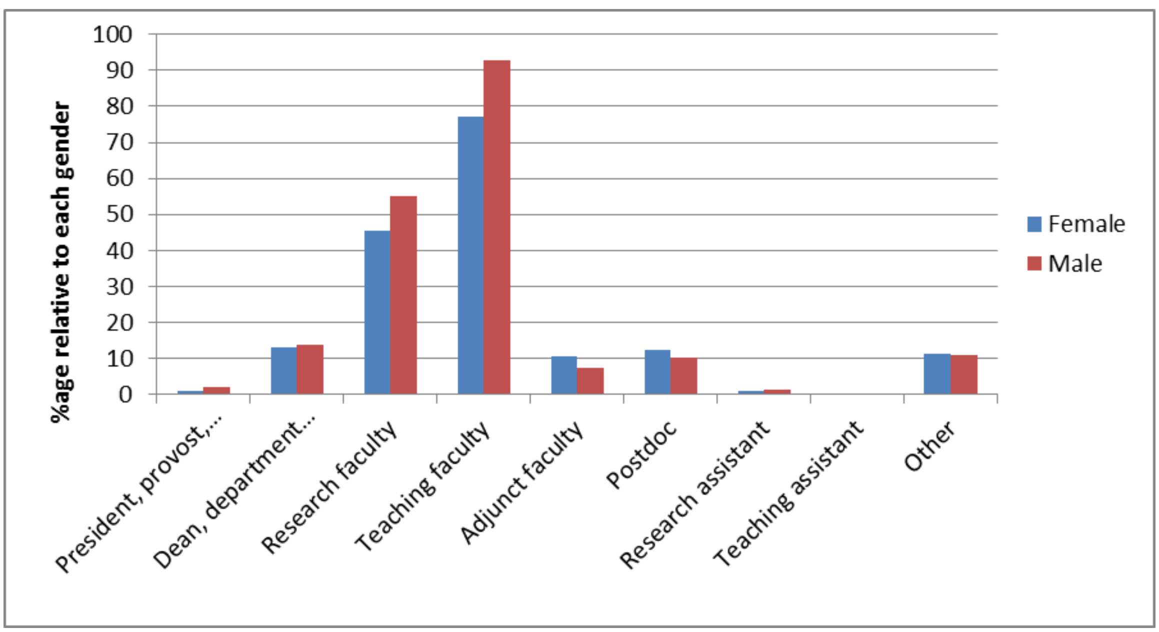


Figure 5 Percentage of female recipients of science and engineering PhDs awarded

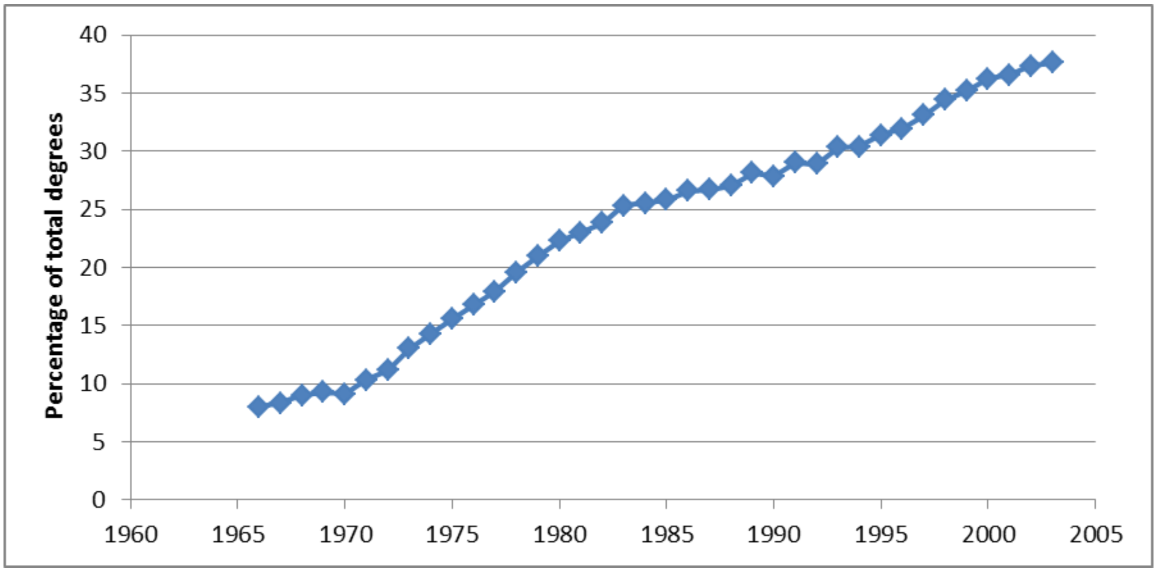


Figure 6 Employment of male andfemale scientists and engineers by age, 1996.

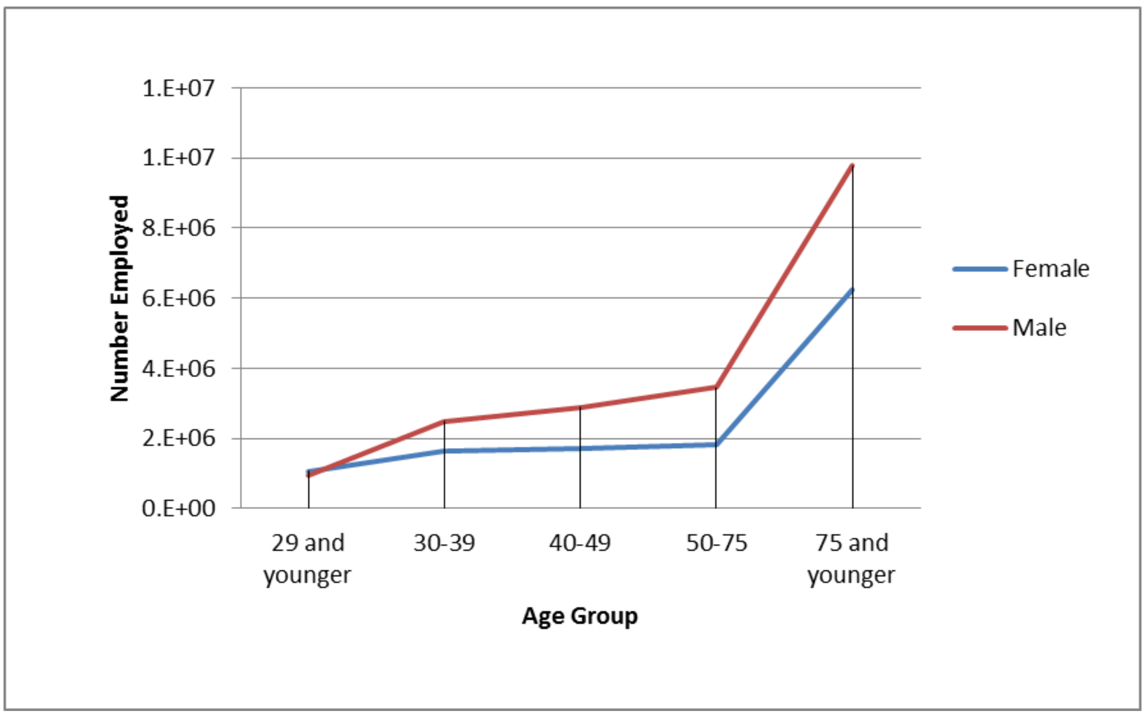
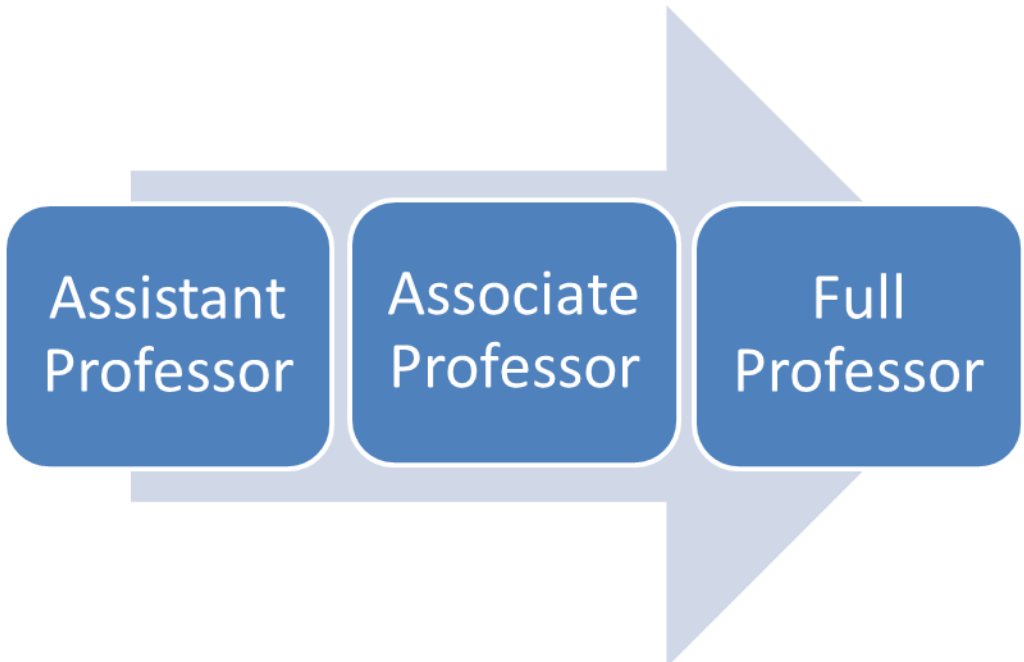


Figure 7 Progression through tenure track in academia.



Section 8 Tables

Table 1 Case Processing Summary of Relative Rate Indices for Person Offense [50]

Relative Rate Indices[1] for Person Offenses, 2008

	Minority	Black	AIAN*	AHPI**
Arrest rate	2.8	3.6	0.9	0.3
Referral rate	1.0	1.0	1.4	1.0
Diversion rate	0.7	0.7	0.8	0.8
Detention rate	1.2	1.2	1.0	1.3
Petitioned rate	1.2	1.2	1.1	1.2
Adjudicated rate	0.9	0.9	1.1	1.0
Probation rate	0.9	0.9	0.9	1.0
Placement rate	1.2	1.2	1.2	1.1
Waiver rate	1.3	1.3	1.8	0.9

[1] All Relative Rate Indices are relative to whites
* AIAN: American Indian or Alaskan Native
** AHPI: Asian, Hawaiian, or Pacific Islander

Appendix A

Questions that helped to guide first expert panel and interviews.

1. What are the factors that contribute to women not advancing in academia?

2. What are factors that you do not believe play a role in the system?

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3. How do these factors vary across disciplines/departments?

4. How do these factors inter-relate?

5. What are some of the effects of women not advancing?

6. What interventions have we had to try to advance women in academia?

7. What are the effects of these interventions?

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8. What interventions should be done?

9. Is there anything else that you would like to discuss about the topic of women in academia?