ACCELERATING THE GROWTH OF THE PARTICIPATION OF WOMEN* IN ENGINEERING?
*AND UNDERREPRESENTED MINORITIES

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ABSTRACT
Participants of the NAMEPA/WEPAN conference typically believe there are activities that should be engaged in so that the growth of the representation of women and minorities in engineering is accelerated. In this paper we focus on a model developed to represent the factors that influence the involvement of women in engineering. In many respects these models could be generalized to apply to any group; however, the actual model developed is based on numbers seen in women in engineering. Our goal is to use such a model to frame a discussion that will lead to a greater focus on how to accomplish faster change in increasing the proportion of engineers who are women. The model is used to determine which factors are likely to have the largest impacts on changing the growth of women in engineering in a specified time frame.

INTRODUCTION

There are multiple levels to examine in the participation of women in engineering. The first issue to examine is the participation in pre-college coursework that prepares students for study in engineering. In the 1998 NSF Women, Minorities, and Persons With Disabilities in Science and Engineering it was reported that the gender gap in high school mathematics course taking has disappeared for the most part. Other factors that have been correlated to selection of careers in Science, Mathematics, or Engineering (SME) include: family income, family education history, self-confidence, work and family, availability of role models, peer support, and teaching methods.

The first direct measure for women's participation in engineering occurs at the BS degree level. Women earned 17% of the engineering degrees in 1995 as compared to one percent in 1966. This has risen to 18% in 1999. Women earned more than half of the bachelor's degrees in non-science and engineering fields since at least 1966 and were 59% of these fields in 1995. In the broad grouping of science degrees, in 1995 women earned 73% of the BS degrees in psychology, 50% of the BS degrees in biological/agricultural sciences, and 50% of the BS degrees in the social sciences. Women accounted for 35% of the BS degrees in 1995 in the physical and earth sciences, up from 14% in 1966. Women were awarded 35% of the BS degrees in mathematics and computer science in 1995, a slight increase over 1966. [1]

Women still account for only 11% of the total graduate degrees granted in engineering. Within graduate level engineering programs, the participation of women by field remains uneven with 23% in civil, 19% in chemical, aerospace, materials, and 15% in electrical and mechanical and industrial. Women in 1995 earned 60% of master's degrees, and 53% of doctoral degrees in non-science and engineering fields. [1]

Women make up 9% of the working engineers, but 46% of the U.S. labor force. In engineering only about 5% of engineers hold doctoral degrees, male and females. If you look at science and engineering fields together, there are some short-term trends that show a slight increase in the representation of doctoral women in science and engineering employment: women were 22% in 1995, compared with 20% in 1993 and 19% in 1991. [1]

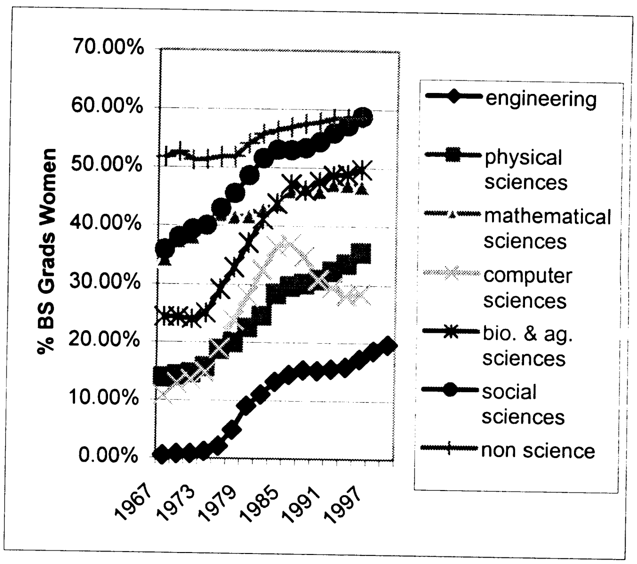

Figure 1 Percent of BS degrees awarded to women by field [1]

One popular theory around why women are 50% in social science, psychology, biological sciences, and agricultural sciences, but not computer science, mathematics, engineering, physics is the "pipeline." This is the model focused on progression through a series of sequential steps required to ultimately enter and excel in a profession. This theory has not proven to help in explaining why engineering is progressing so differently from most other fields in its

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growth of women participants. Between 1983 and 1993, participation of women in the workforce hardly changed but women lawyers increased from 15% to 23%; female executives rose from 32% to 42%; female professors rose from 36% to 43%. [2]

Women's participation in computer work increased and decreased in the proportion of women in the labor force between 1976-1994, but has declined after 1994 even though women in the workforce remains stable. Wright [5] has found women left the field at a higher rate than men, that there were more women leaving than entering the field, and fewer women than men were entering the field. Consistent with Kanter [3] and Jacobs [4], many women are attracted to computer work, so many enter the field, but are made to feel unwelcome and therefore leave the field.

STATEMENT OF MODEL GOALS

The mathematical model proposed is based on several assumptions made by the authors. The first assumption is that we should expect to have 50% women in engineering, based on the approximate population of females in society. This assumption reflects the belief that there is nothing biological about women and the field of engineering that would make 50% participation unreasonable. The second assumption is that the historical and current rate of change in the percentage of females studying and graduating with engineering degrees is low for reasons that can be changed.

With these two assumptions in mind, the goal of our modeling effort is to reflect the primary factors contributing to women choosing to study or work in engineering. In order to make this more reasonable, we have chosen to focus on women's participation at the BS level. We recognize this is just one point in the pipeline and will not fix all points along the pipeline.

GENERAL MODEL OF FACTORS INFLUENCING CAREER CHOICE

Our model is going to follow the influence on career choice from three major areas: the societal impacts, the organizational impacts, and the behavior of individuals in making career choice.

A. Societal Impact

Much of the research that focuses on sociological impacts on career choice, cognitive differences and barriers (structural and normative) consistently show differences amongst genders which can limit opportunities. [6] Structural barriers, internal organizational attitudes that often leave women in "discrepant status", often prevent females, in particular, from considering careers in many fields which are dominated by men. Whereas normative barriers, in which young girls may place limits on their goals and dreams in order to follow a profession, including a strong emphasis on marriage and motherhood, are viewed as appropriate for women. Cognitive differences are often attributed to the lack of positive female role models in a variety of leadership positions. Along with this lack of role models, females are more likely to attribute their success to external factors and failures to internal reasons. With lower levels of internal success attribution females, in general, are less likely to pursue a degree in a field that is not socially seen as normative for women. It is these barriers along with cognitive differences that many social theories are built upon which impact youth, particularly girls, in their decision of career choice.

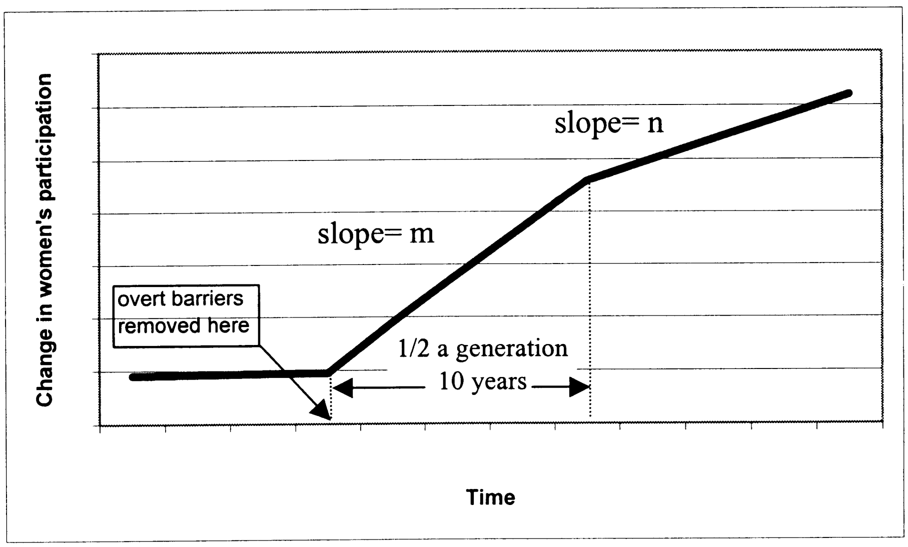

Figure 2 Model for Change in Women's Participation in Fields as Overt Barriers are Removed

As a society undergoes changes in its norms for women, a complex set of factors result in the shifts in different institutions or professions. These factors reflect the propagation of new norms throughout different groups in the society. The feedback of these new norms to new generations define the basic assumptions about what are acceptable. Trying to model these complex shifts is far beyond the scope of this paper. We choose to model these changes by observing the graduation rate of women in engineering and science at the BS level, and extract values to reflect a changing society in the United States. It appears from the curves in figure 1 that in the late 1960's through early 1970's significant changes happened in all of the fields. This was a time when legislative actions and policies removed some of the overt barriers impeding women's entry into the sciences and engineering. In the curves shown, between 1967 and 1977 the average growth rate for the sciences and engineering BS graduates was 0.75%/year, and from 1977 to 1987 the average growth rate was 0.47%/year. In engineering alone this effect seems to have been delayed by 10 years. From 1977 to1987 the rate of change for engineering was 0.62%/year and from 1987 to 1997 the change was 0.35%/year. In our model we will show the current major societal impact on change, SC, to be 0.35%/year for engineering.

The overall societal effects will mask some contributions made by unique cultural influences. Factors such as social-economic status, unique perceptions of gender roles in the culture, perceptions about education, value systems and designation of prestige, and the influences of family, authority figures, and peers will change the societal impact on members of unique cultures. In the US these factors contribute disproportionately as an attenuator or gain to the growth of underrepresented minorities in the fields. The combined effects of a minority culture, within the majority culture, creates a 'tweek' in the societal gains (Figure 3). It is interesting to note that in 1999/2000 the BS graduation of engineers had: 18.5% of the Anglos were women, 34.7% of the African-Americans were women, 25.0% of the Hispanics were women, and 25.4% of the Asian-Americans were women. Since African-Americans and Hispanics were underrepresented in the engineering graduates with respect to their proportion of the US population, and since these groups have higher participation of women, then by increasing these ethnic groups' participation in engineering we would increase the graduation of women. Looking at this another way, we must be sure to address the different ethnic groups' women to assure that the growth of graduation of total women increases.

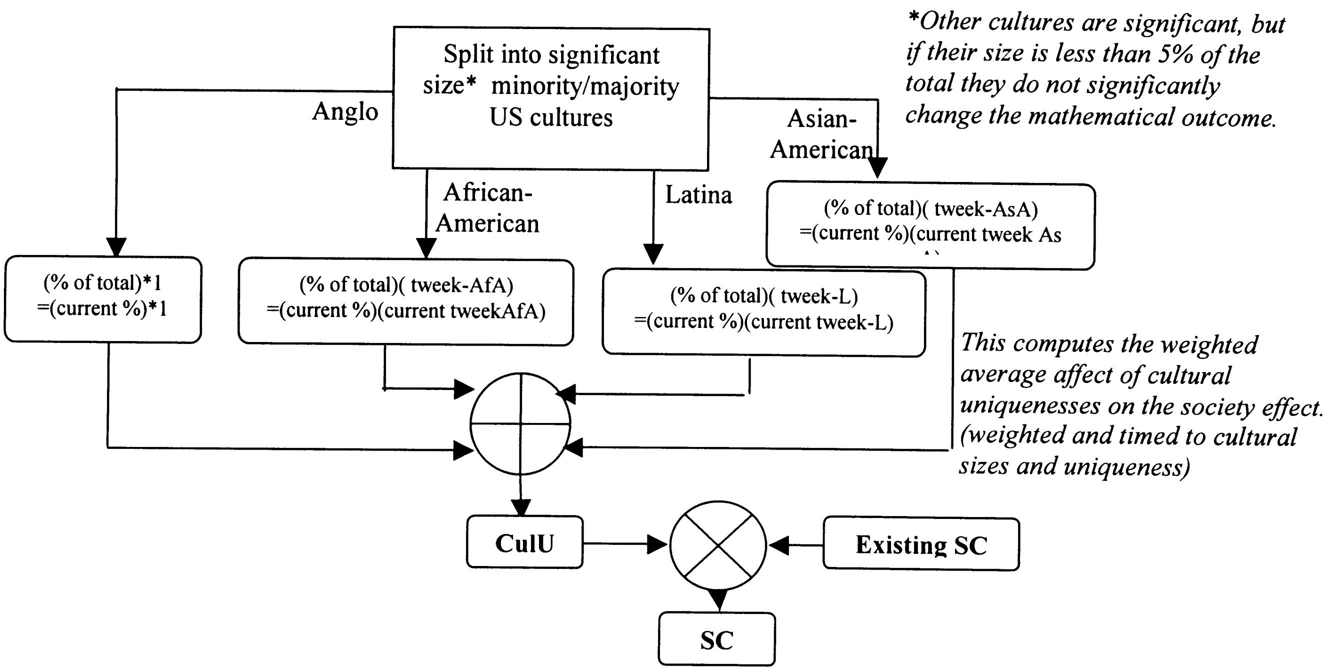

Figure 3 Model for Cultural Affect on Societal Change

B. The Individual Behavior Impact in Choosing a Career

There are volumes of information available for ideas on the behavior and processes involved when children choose a profession. The clear conclusion is that the process of choosing a career is extremely complex and unique to the individual's personal characteristics and life experiences. We will focus on a model developed by Gottfredson in 1981. [7] Her conclusions state that individuals establish certain acceptable career choices as they move through childhood. The choices depend on what careers the child is aware of and whether they keep them as a viable alternative for themself or not. Important stages in this process are:

Age 3-5 children are influenced by size and power, but have little thought about where they will be in the future.

Age 6-8 children orient to appropriate sex roles, and start categorizing certain jobs as being for one role or another.

Age 9-13 children establish a social valuation for different careers. This considers the child's perception of social classes' access to certain careers, the level of the work, its value and prestige in society. The children will keep certain careers as desirable in their aspirations here and eliminate others.

Age 14+ the adolescents start to identify how they may uniquely fit into some of the careers they have kept in their set of desirable options. Self-awareness and esteem, as well as peer influence are major attributes of the choices made here. In addition the strength of the field will influence choices in this period.

One of the main ideas presented by the researchers of the career choice behavior is that individuals need to see many options, have honest self-awareness, and delay the choice until as late as reasonable given their situation. [7]

We choose to model the impact individual behavior choice on the growth of women's participation in engineering as delay factors. Perception of changes in gender roles **(GR)** has a 14-17 year delay before impacting college graduates. Research has shown that short interventions are not effective in changing these gender role perceptions, so we model that a field must visibly have more than a 15% participation rate by women before this can be a viable factor. Perceptions of changes in the value or prestige **(VP)** of a field will have an 11-15 year delay before we should expect significant impact on college graduates. Changes in the strength of the field **(SF)** will have a 4-8 year delay before impacting college graduates. The change in the perceived strength of the field can be approximated, in hindsight, by its overall growth. The percent of women receiving BS engineering degrees is highly correlated with the growth in total engineering degree production ($\rho>0.8$), thus we can expect participation to grow as/if the field grows. Efforts to change how individuals perceive their fit with a field, **(IF),** will have a 4-8 year delay before impacting college graduates. Furthermore, IF impacts will be directly proportional to the number of individuals involved in the effort, unlike the GR, VP, or SF areas. Research has shown that individuals will give up their perceptions on individual fit and strength of the field before they give up any perceptions about which fields are valued and prestigious enough for them. Also, they will give up on a valued or prestigious field before they cross their perceived gender role defined fields. These factors are modeled to impact change by summing them and adding them to the modeled factor for social change, SC.

C. Organizational Aspects

Many organizations continue to be perceived as unwelcoming to women and minorities. Organizational structure and rules have often been established by men for men. There is evidence that as women and minorities enter organizations, the laws that gave them access and protected them, cannot protect them from individual biases of the majority-male workers. Organizations have explicit policies aimed at providing access, but one study shows women and minority candidates often only have access to lower prestige positions, positions of lower pay, positions that dealt only with their race, and positions that were "dead ends" with no next step. [8]

Leighninger [9] attributes differences in power in the social sciences to "gender role stereotyping and an extension of social control in a patriarchal society." Her argument is in line with the contention by Wright [5], and Kaldenberg et al. [10], that the male ideology is the dominant occupational culture. The idea that men should be 'in charge' and women in supportive positions is prevalent in both male and female dominated professions." [2] There is a clear consensus among researchers in all fields that gender and racial inequality in the labor market is "largely due to social control and the structure of the professions."

The total effect of 'gatekeeping organizations' on a field is based on the perception that individuals in society have of these organizations. In our model we are concerned about the perceptions individual's have toward colleges and employers for engineering. We model these effects in two main parts: the feedforward, the apparent invitation and welcoming environment offered by the organizations to women, and the feedback, the apparent presence and success of women in the organizations.

The feedforward factor, **(FF)** has two major components. (1): Organizations that have been traditional male go through periods of time when they make significant efforts to invite women (and minorities) into the field. These efforts are affirmative activities, **(AffA),** and because they are targeted to one group, women, and exclude another, men, there is almost a guaranteed eventual resistance or resentment to these efforts. These reactions will attenuate the gains that could be made by the affirmative efforts. Because affirmative action tends to be based both on gender and ethnicity, the cultural uniqueness must be accounted for in this factor (Figure 4) and (2) organizations can change their structure or operations to become more welcoming to women. This organizational change impact **(OC)** must not negatively affect the strength of the field. This factor can be modeled as the sum of the impact caused by changing operations to accommodate women's needs, changing the operations so that women are equitably motivated by the work, and changing the organizational culture so women succeed equitable to men for their efforts.

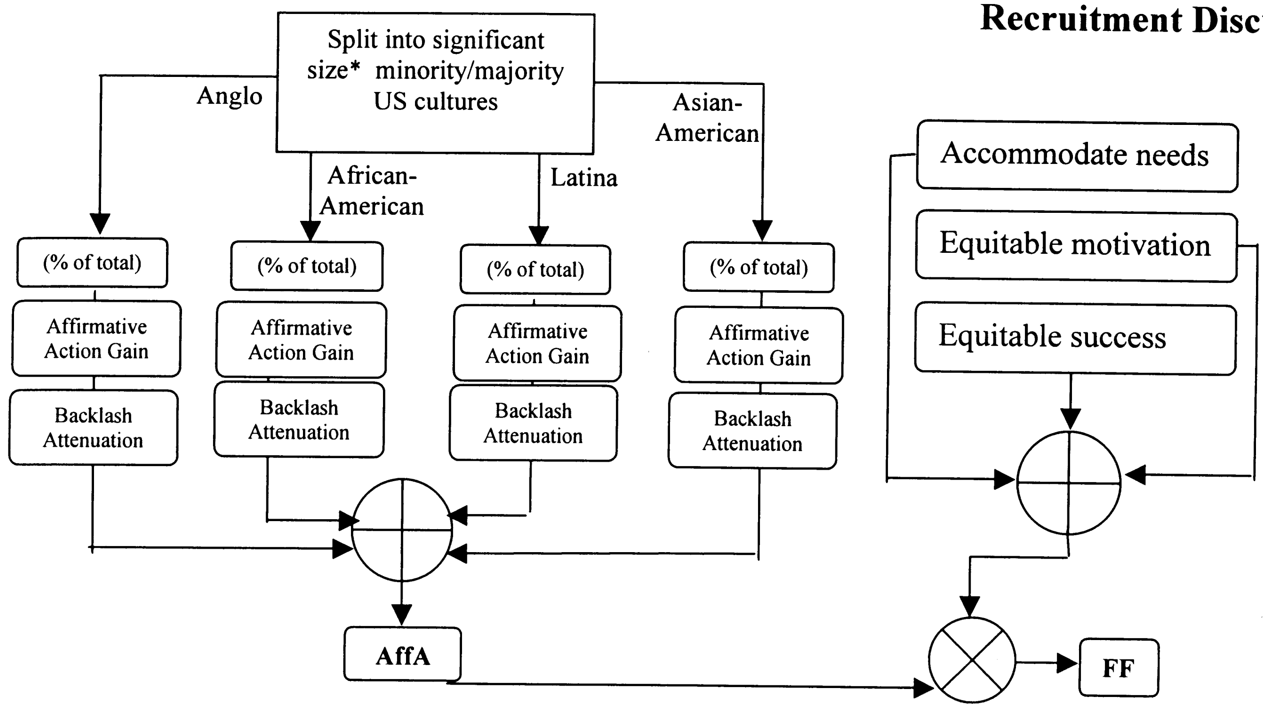

Figure 4 Model for feedforward impact of organizational effects

Traditionally male professions go through 4 stages as they grow in women's participation: a) pioneering women, who overcome all barriers (field<2% women) are present. This period often precedes the removal of most of the overt barriers. The organizations have little impact on the change in participation in this period because they simultaneously have barriers to women's participation, b) unique women, who ignore social norms (field < 15% women), enter the fields when overt barriers are lowered. This was already modeled in the societal change model, c) a lull in the change process occurs while the visibility of a 'resocialized' profession that is inviting to women is growing. If a field is not very visible to society then this delay will be extended, and d) the field is viewed as acceptable for women so growth in participation rises, the gain here amplify the effect of the societal growth. The feedback factor **(FB)** occurs when a field is widely perceived to be socially welcoming to women. Thus, a field has to be well into the third and fourth stages described here before this feedback comes into play. Engineering will reach this stage when women are present at every level of organizations of engineers in a proportion greater than 15%.

MODEL FOR ACCELERATING CHANGE

We pull the factors described in the previous section together to show how the change of women graduating at the BS level in engineering can be modeled. In this model we show:

Expected % of graduates who are women
= Current % of graduates who are women + (SC + GR +VP + SF +IF)(FF+FB) t (1)

where t is the time interval for the change and the other variables were defined in the previous sections.

To explore the areas that are most sensitive in a time interval, we differentiate equation 1 with respect to change. When we differentiate the change factors that are not zero or negligible are:

- DSC/dt - relies upon our efforts to change the participation of different ethnicities in engineering, and the efforts that will encourage women of different ethnicities to participate.
- dGR/dt - can be very large, but has a 14 –17 year delay before it affects BS graduation, and even longer for engineering since women do not comprise 15% of the field yet.
- dVP/dt - can be large, but has a 11-15 year delay before significant impact is seen.
- dSF/dt - can only minimally be changed by intervention efforts.
- dIF/dt - can only be as large as the number of individuals involved in intervention efforts, and will have a 4-8 year delay before impacting engineering graduates.
- dFB/dt - is delayed and can only be affected by making a field and the women in the field more visible to the general public.
- dFF/dt - is composed of dAffA/dt and dOC/dt. Currently the backlash concerning dAffA/dt has not helped engineering colleges to look more inviting to women. (We are not saying this differential is negative for the entire US, but it may be approaching a negative value. This leaves dOC/dt

as an important area for accelerating the growth of women in engineering, but the area that possesses considerable resistance to change.

CONCLUSION ABOUT ACTION

Clearly the model to describe the complex processes in societies, organizations, and individual's choices that influence the participation of women in a field is difficult. Many would say no model can be accurate enough to be worthy of concern; however, even if people do not state the model they are using, people have a model to decide upon actions they support to affect change. Based upon the model developed here, the first conclusion would be that if we keep doing everything we are doing today, and no negative feedback about the engineering organizations or the strength of the fields occur, then in 90 years we may see the BS graduation rate of women approaching 50%. If our goal is to see more significant changes in the next decade, then on top of everything happening today, we have to focus on some significant intervention strategies. The model points to only two interventions which could promote significant change in the participation of women in the next five to ten years. They are to show tens-of thousands of high school girls that they could fit well into engineering, and to change the engineering organizations to be more accommodating, motivating, and rewarding to women. Currently it is estimated that possibly 2500 to 10,000 girls participate in programs that help them to understand how they fit well with engineering. Optimistically, this may lead to an increase from about 13,000 women BS graduates to 15,000 in 4-7 years. If we want more change, we will need to expand our intervention efforts significantly. When it comes to changing the actual operation of engineering colleges, we tend to moan about the resistance that will surely be encountered. However, if NAMEPA and WEPAN are truly going to lead in this effort, then we have to give colleges a better vision of what they should be striving to become and supporting them to change into those visions. Now, the dialog begins...

REFERENCES

[1] National Science Foundation. *Women, Minorities, and Persons With Disabilities in Science and Engineering: 1998.* Arlington, VA, 1999. (NSF 99-338).

[2] Tang, Joyce and Smith, Earl (editors) 1996. *Women and Minorities in American Professions.* Albany, NY: State University of New York Press.

[3] Kanter, Rosabeth M. 1977. *Men and Women of the Corporation.* New York: Basic Books.

[4] Jacobs, Jerry A. 1989. *Revolving Doors: Sex Segregation and Women's Careers.* Palo Alto, CA: Stanford University Press.

[5] Wright, Rosemary 1994. "Male Flight from Computer Work: A New Look at Occupational Resegregation and Ghettoization.: *American Sociological Review* 59:511-536.

[6] Fiorentine, R. (1988). "Sex difference in success expectancies and causal attributions: Is this why fewer women become physicians?" *Social Psycholgy Quarterly,* 51, 236-249.

[7] Gottfredson,L.S., (1981), "Circumscription and compromise: a developmental theory of occupational aspirations" *Journal of Counseling Psychology,* 28:545-79.

[8] Reskin, Barbara and Padavic, Irene. 1994. *Women and Men at Work,* Thousand Oaks, CA: Pine Forge Press.

[9] Leighninger, L., (1996). Social Work: The Status of Women in a "Female Profession." In –J. Tang and E. Smith (Eds.), *Women and Minorities in American Professions* (pp. 111-134). Albany, N.Y.: State University of New York Press.

[10] Kaldenberg, Dennie O. and Gobeli, David. 1995. "Total Quality Management Practices and Business Outcomes: Evidence from Dental Practices." *Journal of Small Business Management* 33:21-33.

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