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What Difference Has Feminism Made to Engineering in the 20th Century?

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Introduction

Until the last quarter of the twentieth century women have been very scarce in engineering, so the impact of feminism on engineering might seem like a topic with a very short history. However, somewhat broader definitions of feminism and of engineering bring to light very significant influences of the women's reform movement of the first half of the twentieth century on industrial and municipal engineering. I first conceptualized this influence as women pushing for regulation that in turn transformed engineering. But as I went deeper into the material I discovered a tremendous amount of travel over the line between reformer and expert. In the first half of the century women forged especially close links between reform and technical expertise. Women pushing for reform, particularly before they gained the vote, found that scientific or technical expertise provided crucial legitimacy, while women in technical fields found that the new reform enterprises provided career opportunities that were not otherwise available. Many of the women who made a notable contribution to engineering in the first half of the twentieth century were influenced by the women's reform movement. The second wave feminist movement of the later part of the twentieth century defined feminism in different ways and during that period women in engineering and related fields achieved more equality but did not find feminism as useful as a source of opportunity. I want to examine how different kinds of feminism had different effects on engineering and the context of engineering work in the early and late twentieth century.

The concepts I have used already—feminism, the women's reform movement, and the participation of women in engineering—overlap in confusing ways. I would like to define as

feminist people who work for the advancement of women and at least considering any group of women who work together as women either directly for the betterment of women or for some social good where they believe they can make a special contribution because they are women. I want to include women reformers of the late nineteenth and first half of the twentieth centuries, particularly those who have been lumped into the Progressive Movement. I am interested in women who organized as women, even if their goal was to save birds, and in women who felt they had a special role to play in mixed organizations because they were women. I was at first defensive about whether I could call these women feminists, as they saw themselves fighting more broadly for a fairer society rather than centering their analysis on the rights of women. However, the more I read of the writings of these women, the more feminist they sound to me. They focused on issues of the treatment and role of women, even though they might want laws to protect women workers rather than equality between women and men. Most were not interested just in one area of reform but worked on a number of different issues that we would call "women's issues."[1]

Feminism broadly defined can be categorized in many ways, but for the purposes of this paper it is sufficient simply to differentiate between difference feminism and equal-rights feminism. Difference feminists believe that women have something special to contribute because they are different from men, either essentially or because of their upbringing and/or cultural history.[2] The experiences of middle-class American women in the late nineteenth century led them to develop a vision of what they could contribute as women, and that particular vision, sometimes called social feminism, provided themes for a series of movements in first half of the twentieth century that I will lump together as the women's reform movement. The difference feminists of the women's reform movement believed that as women they had a special

contribution to make to improving society. They usually argued that this was because women were essentially different from men—more moral, more concerned with protecting the weak, having the special skills of housekeeping. Second-wave feminism developed a different idea of women's special contribution, often arguing that difference was cultural rather than essential and defining such characteristics as cooperation, caring, and fairness as women's special strengths. But in both cases women believed they brought new ideas and approaches because they were women.

Equal-rights feminists believe that the differences between men and women are not significant and that the goal should be equal treatment of men and women. Early twentieth century equal-rights feminists mostly made philosophical arguments for the rights of women. But some women who moved into formerly male professions in the early period took a quiet equal-rights stance, hoping that if they asked for no special consideration because they were women they could prove themselves worthy of equal treatment.[3] In second wave feminism equal rights became a central policy goal. Many second-wave feminists argued that women were not necessarily different from men except in a few narrow areas (such as breastfeeding) and that women should fight for a society where equal treatment of men and women would result in equal participation in all possible social roles.

These broad strategies had many variants and sometime even got mixed together, but when women worked for a larger role in public life it made a difference whether they did so by arguing that they had a special role or by arguing for equal treatment. My interest in the two kinds of feminism is not a philosophical one but a practical one: what results came of women taking these two different approaches for the field of engineering? Both approaches to feminism coexisted throughout the twentieth century, though difference feminism was the more common

strategy of women seeking to have a political influence in the first half of the twentieth century while equal-rights feminism played that role for second-wave feminism. Both kinds of feminism had advantages and disadvantages for women seeking to influence and participate in the public and professional worlds. The two kinds of feminism provided different opportunities both for individual women and for society as a whole, and it is on those opportunities that I want to focus.

Difference feminism provided a way to get a foot in the door, by arguing that women's participation was needed on particular topics. It could also provide women with a chance to make innovative contributions to whatever field they were entering, since by definition they brought new ideas and new approaches. However, difference feminism tended to limit opportunities for women to topics or fields that were perceived as particularly suitable for women. The theory of complementary or separate but equal roles for men and women almost inevitably resulted in practice in unequal treatment for women.

Equal-rights feminism insisted that women gain access to the mainstream. Women had the opportunity to work in any area that they chose, not just those that fit some theory of women's special role. However, equal-rights feminism made it difficult to challenge existing male-defined ways of doing things because women accepted on the basis of equality did not want to call attention to themselves as different from men. Even a better idea was dangerous if it might be seen as particularly female and therefore point to women as different and potentially unequal.

In considering the results of these two approaches for the field of engineering I need to define engineering broadly as well, though I will not be considering the entire domain of technology. Historians studying issues of gender and technology have focused recently on consumer products and on the users of technology, as shown in other chapters in this volume.[4] While those are probably the richest areas for gender analysis of technology, I have chosen in this

chapter to focus instead on the fields in which people who call themselves professional engineers work and some closely related fields. I want to ask how feminism influenced the design of factories and of urban infrastructure and the profession of engineering more generally. While this is probably a less important question than the one about consumers it is still a valuable one, and because I teach an introductory history of technology course for freshman engineers I have a particular interest in the history of professional engineering.

In looking at the impact of feminism on engineering it is important to consider not only the intellectual development of engineering but also the social context in which engineers must fit their work. One of the key changes in the practice of engineering in the twentieth century was the growing significance of regulation and, more generally, changing attitudes towards the responsible use of technology. Consumer protection, industrial health, and the environmental movement have given engineers increasing responsibility to protect workers, consumers, society, and the environment from harm. Is there anything engineers do that is not hedged in by regulations and concerns about product liability? Engineer and writer Samuel Florman goes so far as to argue that engineers no longer need codes of ethics because everything that is unethical is now illegal and so all that engineers need to be told is "Do not break the law."[5] I don't agree with Florman about ethics, but his point shows how significant he sees the regulatory environment to be to the practice of engineering.

For the early period, I will argue that women reformers played a key role in changing the regulatory environment. From the late nineteenth century through the 1930s, women shaped reform movements in the United States, from the Progressive Movement to industrial health to the conservation movement to the New Deal. Most of these women were difference feminists, and most of the issues that concerned them had to do with the results of rapid industrialization

and urbanization. Some women saw their role as ameliorative, while others saw the issue in a larger context and believed that women stood outside of the competitive world of unbridled capitalism (greed) and represented an alternative set of values. In both cases they often saw big business as at least in part the enemy. These women played a central role in redefining government and corporate responsibility away from the laissez-faire model and in creating our regulatory environment and our expectations of government responsibility.[6] They also participated in technical debates, created job opportunities for women, and brought new, reform-inspired ideas into a number of technical fields. Reform played a large role in the careers of most of the women who had an impact on engineering in the early period.[7]

The influence of difference feminism faded considerably in the middle of the twentieth century, and when a second wave of feminism developed in the late 1960s and early 1970s its most influential wing emphasized equal rights and explicitly rejected many of the old arguments for difference. The fight for equality succeeded in bringing more women into engineering, but those women did not bring many feminist ideas with them. A new generation of difference feminists was developing theories that challenged engineering more radically than the old reform movement, but women engineers, who were at most equal-rights feminists, did not use that critique as either a source of either job opportunities or new approaches to professional problems. Women engineers are today more likely than men engineers to study environmental engineering and to be concerned about the impact of technology on society. However, the gap between feminist critique and the culture of engineering has been very difficult to bridge.

Women, Reform, and Engineering before World War II

In the period from the 1890s to World War II, the difference feminists of the women's reform movement had some direct impact on engineering and also made a tremendous difference to engineering by providing an essential part of the push for fundamental changes in attitudes towards personal, corporate, and social responsibility. Recent scholarship has increasingly shown that women reformers played a leading role in the Progressive Movement, and more broadly in changing public culture.[8] In addition, women worked in specific areas such as industrial health with direct impact on engineering, and women who practiced in technical fields carried the ideas of reformers into engineering. In this section I will examine these issues on three levels. First, I will summarize the argument that women reformers deserve central credit for many of the reforms achieved by what is most commonly known as the Progressive Movement. Second, I will examine the contributions of women reformers to a number of fields where reform efforts had a direct impact on engineering. I want to argue not only that women reformers pushed successfully for regulation that changed engineering practice but also that women used the reform community to build technical careers. Third, I will suggest that this pattern of reform as a source of career opportunities may have held even for women engineers.

<B> The Women's Reform Movement and Progressivism

The development of regulation involved not just changes in individual laws, but also a broader shift in attitudes towards responsibility. Late-nineteenth-century industrialists fought worker and consumer protection not just out of cynical self-interest, but also because they held to a traditional belief that ordinary people could and should watch out for themselves. However, as technology became more complex and businesses bigger, individual responsibility did not work as well. Along with this growing need for regulation came the idea that society in general and

government in particular had a responsibility to protect those who could not protect themselves, and more people were put in that category. To what extent should feminism get credit for these changes in attitude?

Nineteenth-century feminism was part of a larger women's reform movement, in which women sought to bring society more in line with the values of middle-class women. From the start, women's campaigns such as those against alcohol and prostitution claimed that their goal was to protect women. Over the course of the nineteenth century, reform-minded middle-class women moved towards a closer relationship with the people they wished to help, particularly through the settlement house movement in which reformers lived in a community center in the neighborhood they served. They also moved from a moral analysis based on individual sin to a view that called for reform of society, and particularly of industrial capitalism. When moral suasion alone failed, women reformers turned to the legislative arena to try to accomplish their ends by regulation. By the end of the nineteenth century, activist women had established a tradition of commitment to social reform by broadly political means as well as by direct community service. This interest in political action led many women to a conviction of the necessity of female suffrage, whether or not they believed that women should have the same rights and responsibilities as men.[9]

Women's historians have increasingly shown that the women's reform movement drove progressivism.[10] William Chafe argues: "Almost everything that we find admirable about the Progressive Era appears to have been associated in one way or another with women reformers carrying out the politics associated in the nineteenth century with women's domestic concerns."[11]

The home missionary and settlement house movements gave women activists greater experience with the real needs of the poor, and one important outgrowth of this was the

significant role of women in lobbying for protection for workers and consumers. Nancy Cott writes:

> As pressure from women's voluntary organizations had been instrumental in making local public health and school departments assume some responsibilities for sanitation and for children's safety, in leading states to institute social welfare and protective labor legislation, and the federal government to establish pure food and drug laws, likewise it was under pressure from women's voluntary groups, principally the National Women's Trade Union League and the National Consumers League, that the Women's Bureau was established in the U.S. Department of Labor to investigate the conditions and protect the interests of wage-earning women.[12]

Women reformers fought for consumer protection: the Pure Food and Drug Act of 1906 was the culmination of 103 bills introduced in Congress between 1880 and 1906 to control interstate commerce in food and drugs.[13] They pioneered protective labor legislation by lobbying for minimum wage laws and laws regulating working hours that at first applied only to women and children, laws that later provided a model for a larger social contract when the New Deal finally overthrew the tradition of limited government.[14]

Women reformers were often more effective than men because they found ways around politics as usual. The reformers found that they could fight the political machines that controlled many cities only by the force of public outrage. They saw their goals as a matter of community morality, so they sought publicity and appealed to public opinion. Kathyrn Sklar argues:

"although women did invent the *methods* of interest-group politics as we know them in the late twentieth century, they thought of themselves as representing society more generally—often in explicit contrast to the self-interested politics pursued by their middle-class and working-class male contemporaries."[15] Sklar concludes a study of two Progressive labor reform organizations: "Through grassroots mobilization women's organizations succeeded in accomplishing reforms that male expertise and power could not initiate."[16]

Women professionals often got their start in and maintained strong ties with the women's reform movement. Alice Hamilton's biographer writes: "As they struggled to integrate new options with traditional standards of womanliness, many women of Hamilton's generation felt a shared sense of female possibility that propelled them to unprecedented achievement in the public sphere."[17] Anne Firor Scott points out that professional women remained deeply involved in and influenced by voluntary organizations: "Women doctors and lawyers, and indeed professionals of all kinds, took a continuing part in one or several associations and brought to the shaping of a distinctively female professional style the background, training, and values acquired there."[18] Robyn Muncy argues that the new women's professions "contained as part of their professional creeds many of the commitments of the progressive reformers who gave them birth" and that those professions actually served to "socialize subsequent generations of aspiring professional women into a common reform culture."[19] This women's professional/reform culture sustained and influenced many professional women, even in fields like engineering where women were a tiny minority.

While the women's reform movement had a wide range of sometimes conflicting goals, these women often saw themselves as organizing or bringing special contributions as women. The women's reform tradition lost its illusions of unity after the achievement of suffrage and the

temporary victory of prohibition.[20] But women still believed that they could make a difference as women; women's voluntary associations were most active in the period "after women became voters and before a great proportion of them entered the labor force."[21] Most of these women worked according to a pattern of women's organizing to protect those that they saw as unable to protect themselves, though different groups had different priorities and politics. Many argued explicitly from women's values, and such women had an idealism that was made possible by a culture that expected women to inhabit a sphere separated from the business world.[22] This idealism had limits; middle- and upper-class women more often sought to save the environment through the Audubon Society rather than to question the practices of their husband's businesses. But they could be very effective; they saw politics as people and so their strategies were usually practical and down-to-earth.

While the reformers usually saw business rather than technology as the object of their analysis, this large women's reform movement had a substantial impact on engineering practice. Most broadly, government regulations created new standards, and businesses had to change their production systems to meet those standards. New requirements to protect workers meant new safety features on machines and new equipment to make the workplace safer, for example by better ventilation. Later on it meant new technologies to avoid or remove pollutants. In the following sections, examples of reform efforts closely related to industry and to municipal engineering show more specifically this impact of reform on engineering.

<B> Industrial Medicine

One of the first places where reformers fought for regulation that impacted engineering was in the protection of workers' health. One of the key figures in this movement, Alice

Hamilton (1869-1970), provides a particularly clear example of how the women's reform movement shaped the careers of women in technical fields. Women doctors played a disproportional role in the development of public health and health reform in general.[23] Women did not create the sub-field of industrial medicine, but they were some of its most influential early practitioners. In particular, Hamilton played a central role in defining issues and tactics for the field based on her experience in the settlement house movement. In turn, industrial medicine became a prototype of investigation and regulation that played a key role in shaping the regulatory environment today. Much of what we know of the dangers of pollution to human health started from industrial medicine, as did many of the approaches to how to regulate those risks.[24]

Alice Hamilton brought together two new movements in the 1890s: the rise of scientific medical research and the settlement house movement. Hamilton did her medical training at the University of Michigan, receiving a laboratory-based medical education.[25] In 1897 Hamilton took a position as a professor at the Woman's Medical School of Northwestern University and went to live at Hull House, the most famous settlement house.[26] By the time Hamilton arrived at Hull House, the settlement movement had already broadened its interests to include industrial as well as neighborhood conditions. In particularly, Florence Kelly had done an investigation of factory conditions that led, through lobbying of the Kelly and other Hull House residents, to a state factory act in 1893 limiting working hours for women and restricting child labor.[27]

Lobbying for regulation became a key strategy of the women's reform movement in particular and progressive reformers in general, and expectations of the role of government shifted rather dramatically in the first quarter of the twentieth century. The Supreme Court overthrew a state law restricting hours for men in 1905 on the grounds that it violated the

freedom to contract, but it allowed a law restricting hours for women in 1908 on the grounds that the state had power to protect the health and welfare of the community, in this case the children and unborn children of working women.[28] Other reformers focused on accidents and the need for safety regulation, leading to the creation of the U.S. Bureau of Mines in 1910, to state legislation, and to federal laws regulating railroads. Lobbying for state and, eventually, federal regulation became the preferred strategy of the period before 1920.

Alice Hamilton's struggle to put together her interest in scientific research in medicine and her commitment to reform drew on these models. About 1907 she became aware of work by muckraking journalists on the dangerous trades and began to read the European literature on lead and mercury poisoning.[29] This fit into the larger trend of the development of workers compensation, but Hamilton was one of the first to call attention to industrial diseases in the United States.[30] Appointed to the Illinois Commission on Occupational Diseases in 1908, she took on the difficult problem of epidemiological investigation when neither factory owners who wanted to avoid responsibility nor workers fearful of loosing their jobs would talk openly of health problems.[31] Her work led to an occupational disease law in Illinois in 1911.

Hamilton was not the sole founder of the field of industrial medicine, and other pioneers were men, but Hamilton played a role so central that her approaches significantly shaped the field. She did a series of investigations for the U.S. Bureau of Labor, not only investigating various industries but trying to persuade factory owners to improve conditions (there were not yet federal laws with enforcement powers). The work of Hamilton and others like her (including a significant number of women in the second generation of experts on industrial medicine) led to the use of respirators, to exhaust and sprinkling systems, and to occupational disease laws in several states before 1920.[32] In 1919 Harvard University hired Hamilton as an assistant professor

in a new degree program in industrial hygiene at Harvard Medical School. In order to get Harvard to hire a woman professor, the dean of the medical school had to argue to Harvard president A. Lawrence Lowell that "she is greatly superior to any man that we can learn of for such a position."[33]

During the period of Hamilton's career, the tactics of the women's reform movement shifted as political realities changed. Before World War I the reformers concentrated on state legislation and had considerable success in more progressive states. Frustrated by more conservative states and by the declining political role of progressivism, reformers increasingly turned their attention to federal regulation.[34] In the period from 1916 to 1919 Congress passed a series of laws attempting to regulate child labor, but the Supreme Court declared them unconstitutional.[35] Florence Kelley led a fight for a constitutional amendment, which passed Congress in 1924 but failed state ratification.[36] During the more conservative 1920s, reformers turned increasingly to a strategy of publicity. When the political climate changed again in the New Deal, women reformers were ready and waiting and played an important role in a number of New Deal programs.

Through her life, Hamilton's tactics derived from her involvement in the settlement house movement. She participated in the women's reform community throughout her career and worked for a number of radical causes, including birth control. She championed women's role, although she argued against the ERA because she believed in special protection for women and she did not hesitate to use feminine sympathy, appeals to chivalry, and patrician confidence as tools in her work. [37] In the 1920s Hamilton emphasized the power of publicity. In the case of radium poisoning of watch dial painters, she wrote of the reaction of the manufacturers at a national conference in 1929: "It is, after all, the weapon of publicity which we hold up our

sleeves that impresses them and makes them ready to do what we tell them to."[38] In the New Deal Hamilton worked on health and safety standards for the Department of Labor under Frances Perkins (whose mentor had been Florence Kelley).[39] The values and tactics that Hamilton brought from the settlement house movement shaped a field that later provided important models for investigations of all sorts of technological hazards.

<B> Women in the Conservation Movement

Women also contributed directly to the development of regulation of technological hazards through the conservation movement. The women's reform movement served as an important driver of the conservation movement, even though the well-known leaders of the conservation movement were mostly men. Late-nineteenth-century women saw conservation as an extension of their political activities; one recent study explains: "Women came to realize that birds were defenseless creatures, and bird slaughter constituted a poor example for youth that was contrary to Christian values."[40] Women were the founders of significant portions of the conservation movement in the late nineteenth century, and even after men took over the leadership, women provided much of the labor and shaped the movement by the work they were willing to do and the political savvy they had gained from other reform efforts.

Women participated in most of the important early conservation groups (except those that focused on hunting) and founded some of them. The Appalachian Mountain Club admitted women from its second regular meeting, in 1876, and the Sierra Club from its beginning in 1901.[41] The first Audubon societies were founded in 1886 to save birds by discouraging women from wearing hats with feathers; they quickly turned to the tactic of taking women to see birds in the wild so that they would not wish them to be killed to provide feathers for hats.[42] Women

founded many state Audubon societies; men took over the leadership only with the formation of a national association in 1905.[43]

Women's clubs played an important role in the early conservation movement. For example, in California women from the state suffrage movement moved into women's clubs that formed the California Federation of Women's Clubs. At the first meeting one leader said:

> The preservation of the forests of this state is a matter that should appeal to women. While the women of New Jersey are saving the palisades of the Hudson from utter destruction by men to whose greedy souls Mount Sinai is only a stone quarry, and the women of Colorado are saving the cliff dwellings and pueblo ruins of their state from vandal destruction, the word comes to the women of California that men whose souls are gang-saws are meditating the turning of our world-famous Sequoias into planks and fencing worth so many dollars.[44]

The group became involved in an effort to preserve the Calaveras Grove of redwoods, lobbying for the creation of a national park first in Congress and then, when a bill to purchase the land failed to pass, with a petition drive that presented 1,500,000 signatures to President Theodore Roosevelt in 1905.[45] The General Federation of Women's Clubs moved into conservation activities at the turn of the century; its member organizations were particularly active in lobbying for the creation of national parks.[46] The national organization formed a forestry committee that coordinated efforts for forest and wildlife protection. One man involved in the fight for national parks wrote of women: "It is they who get the men started. Their federated clubs are invaluable as local propagandists and ground breakers. If once women see the light, the militant kind will

fight forever against any odds."[47] Even the Daughters of the American Revolution paid significant attention to conservation issues, leading an effort to preserve Niagara Falls from being diverted entirely for power production.[48] Women saw conservation as an expression of traditionally female values such as "nurture, prudence, the protection of life, [and] a love of beauty."[49]

After 1910 the conservation movement came to be dominated by professional advocates of forest management and sportsmen, and women became less visible.[50] But in the 1930s reformer Rosalie Edge continued the argument that women brought a critical perspective. Edge came from a prominent New York family and had been deeply involved in the suffrage campaign, where she learned the power of making news.[51] She moved into conservation issues as a leader of a fight against hunting and commercial interests in the Audubon Association. Edge went on to work closely with the Roosevelt administration to advance New Deal projects relating to conservation.[52] She wrote "I wish more women would work for conservation. Most of the conservation measures are so closely related to business that it is sometimes difficult for men to take a strong stand on the side of the public interest. But women can do it, and they should."[53]

Women in conservation believed that they had a special responsibility to work for the protection of nature. In emphasizing nature study they developed and used expertise and public education. They saw themselves as standing outside of the process of industrialization, seeking to preserve what they saw as a heritage for future generations. While women in the conservation movement did not specifically seek to advance women, they used the core ideas of difference feminism to define their role and to push the conservation movement in a direction often quite different from the ideas of its male leaders. While comprehensive regulation of pollution came

later, the conservation movement in this period did achieve local limits on industry, such as limits on diversion of water from Niagara Falls.

<B> Municipal Housekeeping

An overlapping group of women reformers took an even more central role in a movement called "municipal housekeeping," seeking to clean up cities growing increasingly chaotic in a time of rapid urbanization. Their work included everything from legislation to planting trees, but it also involved such projects as studying and advocating the building of municipal plants for water purification, sewage treatment, garbage incineration, and slaughtering.[54] Women involved in these projects stressed public education and political action, but they found that scientific and technical expertise was their best route to legitimacy, particularly when they could not vote. A critique of the results of women's work in one town for a more sanitary slaughterhouse suggests the way women used expertise to fight exclusion: "After working for years to get the abattoir and telling the council what features were necessary to make it efficient and sanitary, not one of the women was put on the advisory committee, even, when it was being built. It is still far from perfect…"[55] In other cases women took their new expertise into jobs; a number of cities hired women inspectors to enforce new regulations.[56]

A key founder of the field of municipal housekeeping, Ellen Swallow Richards (1842-1911) clearly saw herself as a reformer and found the reform movement to be a source of career opportunities.[57] After graduating from Vassar, Richards could not find a job in her chosen field, chemistry, so she applied to MIT for further study. MIT admitted Richards as a special student in chemistry in 1870 in order to avoid setting a precedent for coeducation.[58] Richards found employment at MIT after finishing her training and marrying a young professor. She did

extensive research on municipal water quality and established a woman's laboratory, where in response to growing concerns in the women's reform movement over the purity of foods and drugs, she increasingly stressed chemistry's value to the homemaker. When MIT began admitting women as regular students in 1878, the separate women's laboratory faded out, and in 1883 Richards became an instructor in sanitary chemistry, a position she held until her death in 1911. Most of her work concerned safe drinking water and the composition of foods.[59]

Like Alice Hamilton, Richards combined scientific training and a reform commitment. Richards believed that scientifically trained women could play a special professional role in helping the poor. She transformed the Boston School of Housekeeping from a school for servants to a training center for women managers and administrators—one teacher, Marion Talbot, went on to a position of Dean of Women at the University of Chicago.[60] Richards worked to make the new field of home economics more scientific and more professional: she envisioned "a vanguard of scientifically trained women and men who would act as social engineers."[61] Her vision shaped the early years of the American Home Economics Association, whose original statement of purpose read: "The object of this association shall be to improve the conditions of living in the home, the institutional household, and the community."[62] Richards also trained many early sanitary engineers and passed on a reform vision to the men who became leaders of the field. In the foreword to a 1911 textbook in sanitary engineering Richards called for the sanitary engineer to be a teacher of the public as well as an expert and a leader and to seek to apply engineering "for the benefit of the people with the same energy and business sense as has been used for the profit of the individual."[63]

In the first half of the twentieth century a significant number of women became experts in municipal housekeeping topics, though in many cases they did not have the technical training and

academic legitimacy of Richards. One example, Caroline Bartlett Crane (1858-1935), started her career as a Unitarian minister. Influenced both by the social gospel movement and by the settlement house movement, she believed that the church should take a leadership role in social reform. She took graduate classes in sociology at the University of Chicago and was also active in the suffrage and temperance movements. [64] She married a physician in 1896 and retired from the ministry in 1898 because of ill health. In 1901 she returned to reform work through a local women's club, turning her attention to sanitary conditions in slaughterhouses, health care in poorhouses, and cleaning up the streets of Kalamazoo. Her efforts in Kalamazoo were mostly unsuccessful, but she became widely known as a lecturer and took her involvement in urban reform issues to the national level by serving on committees of the General Federation of Women's Clubs.[65]

Crane became so well-known as an expert that she received contracts to survey sanitary and social conditions in sixty-two cities, from Daytona, Florida to Minneapolis, Minnesota. In many cases the impetus came from women's clubs, but Crane insisted on authorization from state or local officials. She used publicity as her main weapon, taking local leaders and the press with her on her tours and holding a public meeting at the end. She generally received a consulting fee of $100 a day. [66] She studied such topics as: "water works, sewers, street sanitation, garbage collection and disposal, the smoke nuisance, milk supply, meat supply, markets and food factories, hygiene and sanitation of school houses, housing problems, almshouses and jails."[67] Her Minnesota survey resulted in the publication of a 224-page book entitled *Report on a Campaign to Awaken Public Interest in Sanitary and Sociologic Problems in the State of Minnesota*.[68] She was frequently attacked but her reports often led to reforms and the building of new facilities.[69]

The municipal housekeeping movement shows the complexity of the relationship between reform and technical expertise. Women reformers not only used science to gain legitimacy but also to make alliances with increasingly scientifically trained municipal engineers.[70] Mary McDowell, a settlement house leader and spokesperson for the Women's City Club of Chicago, traveled to Germany to study new methods of waste disposal, particularly the use of modern incinerators. Several years later, in 1916, McDowell and the City Club refused to support a proposed $2 million bond issue without a guarantee that there would be "a competent engineering expert at the head of the waste bureau."[71] Mary Beard's 1916 book on women's civic work stresses at times the role of women inspectors, at other times the need to "take municipal housekeeping out of the hands of politicians [and] put at the head of the 'cleansing department' a sanitary engineer."[72] The women involved in municipal housekeeping did not become members of the professional engineering community, but they had substantial expertise and used it to pressure politicians and experts.

<B> Scientific Management

Reform and technical expertise converged in a different way in the field of scientific management. Women played a particularly significant role in expanding beyond machines the rationalization enterprise that had become central to engineering. Women made a place for themselves early in the scientific management movement and in industrial psychology and also took those principles into home economics.[73] In this work they sought to rationalize the home and humanize the workplace.

The best known of these women, Lillian Gilbreth (1878-1972) earned a Ph.D. in applied psychology from Brown University in 1915 and worked in the field of scientific management

with her husband, Frank Gilbreth, who was a key disciple of Frederick Winslow Taylor. Lillian Gilbreth worked as an equal partner with her husband, and after his death in 1924 she continued their consulting practice. In 1926 she fought successfully to become member of the American Society of Mechanical Engineers, which had only one woman member at the time. However, despite her credentials, some clients backed out of working with her after her husband's death, and Lillian Gilbreth turned to the network of women reformers and professionals to find a niche where she could find work. She took on projects in home economics and worked with government programs for women, professionalizing her existing interest in applying the principles of scientific management to the home.[74] Later Lillian Gilbreth moved back into mainstream engineering again, becoming a professor of management in the School of Mechanical Engineering at Purdue University in 1935.[75] She made very significant contributions in "incorporation into time and motion analysis of psychological considerations… and the establishment of industrial engineering curricula in engineering schools."[76]

Lillian Gilbreth's work had as central themes an interest in the worker as an individual and in the less fortunate. Her most original contribution to scientific management was to introduce for the first time issues of "individuality, worker welfare, and psychological concerns."[77] Martha Trescott sums up Lillian Gilbreth's contribution: "Largely because of her influence and those who followed, management theory and practice evolved away from the strict, stern scientific management of Frederick Taylor and his disciples."[78] The Gilbreths did considerable research on job opportunities for disabled veterans from World War I, using motion studies to find ways to fit the job to the worker rather than emphasizing prosthetics. At the end of World War II Lillian Gilbreth wrote two books with Edna Yost on opportunities for handicapped persons.[79] One of Lillian Gilbreth's most important contributions to home economics was

research on homemakers with physical handicaps.[80] Lillian Gilbreth did not participate in the settlement house movement, but she was involved in women's clubs all her career and worked particularly closely with such clubs in her job as head of the women's division of the Emergency Committee on Unemployment starting in 1929.[81] Ideas about the dignity of the poor and about assisting the less fortunate that seem typical of the women's reform movement were the most innovative and significant aspects of Lillian Gilbreth's work in scientific management.

While Gilbreth did not shape her life around reform commitments, her career shows how women in technical fields could make use of reform issues. When she found herself blocked in pursuing the same kind of career path as her male colleagues, Gilbreth could turn to the women's reform network for opportunities. More significantly, Gilbreth made a major contribution to her chosen field of scientific management because she brought in new ideas that came at least in part from the women's reform network.

<B> Women Engineers

While women were extremely scarce in engineering before World War II, there is some evidence that the pattern of using the women's reform movement as a source of career opportunities existed in engineering as well. More information is needed about early women engineers to pin such a pattern down; at present, problems of definition and sources make it hard to prove. Lillian Gilbreth is an example of the problem of definition; she is on all the lists of early women engineers even though her training was a Ph.D. in psychology. Gilbreth certainly brought new approaches to engineering and was recognized as an engineer, but I want to put her in a different group than women with engineering degrees. I have found no evidence of women trained in engineering schools who took a difference-feminism approach and argued that

engineering needed women's special qualities. But that may be at least in part an artifact of the sources, which tend to take an equal-rights approach and stress the similarity between early women engineers and their male contemporaries. A collection of biographies of women engineers, published in 1946 by an engineer named Alice Goff, clearly seeks to emphasize women's equality with men, not women's different interests. Yet even in Goff's telling, which leaves out such activities as participation in women's clubs, a number of women engineers found key career opportunities through the women's reform network.[82]

As early as the late nineteenth century a handful of women attended engineering school and found work in the field, though in much smaller numbers than in any field of science.[83] The following table gives the percentage of bachelor's degrees in engineering going to women:[84]

[Figure 8.1]

The first pioneering women who studied at engineering schools entered a field in transition. Engineering shifted fairly rapidly from apprenticeship training to school training in the two decades after the Civil War, with the founding both of the land grant colleges and of many private engineering schools. This disturbed an old system of status and made it possible for more different kinds of people to enter the profession.[85] While engineering schools grew at least in part out of a military tradition that automatically excluded women, participants in the industrial education movement that lead to the Morrill Act often believed in providing educational opportunities for women. Except in the South, the majority of land grant colleges admitted women by 1880.[86] Even though those colleges developed separate programs for women, the barriers between women and engineering education had diminished, and a number of land grant colleges had their first woman engineering student before 1900. Martha Trescott has identified a

number of early women engineers, most of whom found their opportunities by working with male relatives.[87]

Women found a few more opportunities in engineering after World War I. Like most wars, World War I brought women into technical jobs that had previously been closed to them, though they almost always lost those jobs at the end of the war. Probably of greater significance for engineering, however, was a larger movement towards coeducation and towards integration of the separate spheres of men and women. Women doctors and scientists in the 1920s increasingly wanted not separate institutions but the same opportunities available to men. Engineering continued to be a very rare career choice for women, but there was at least more room for pioneers.

Women engineers in the interwar years mostly followed a strategy more along the lines of equal-rights feminism than difference feminism, but despite this approach a number of women found key opportunities in their careers through the women's reform movement or the idea of women's special role. Professional women engineers found themselves very isolated; one woman told Martha Trescott in an interview: "I think if I had seen just one more little girl around, I would have felt our isolation as women, but the fact that I was the only one, meant I never really thought about it."[88] Despite this, they often found opportunities because they were women. Olive W. Dennis moved up from a drafting job at the Baltimore and Ohio Railroad in the early 1920s because the president of the company wanted a technically trained woman to make a survey of the whole system with the needs of women passengers in mind.[89] Margaret Ingels, who earned a degree in mechanical engineering from the University of Kentucky in 1916, studied both technical problems in air-conditioning systems and also the impact of ventilating systems on the health and attendance of school children.[90]

Edith Clarke (1883-1959) provides an example of the role of the women's reform movement for a woman with a mainstream career. Despite the opposition of her relatives, Clarke set off to college when she received an inheritance at age eighteen, majoring in mathematics and astronomy at Vassar. She taught for a few years, first in San Francisco and then in West Virginia, before deciding to study civil engineering at the University of Wisconsin. She left after a year to take a position as a computer (person who does calculations) for a research engineer at AT&T, moving up to head the computing department. She then decided on further education because of the opportunities opened by the war, and took a masters degrees in electrical engineering from MIT in 1919.[91]

By the time Clarke finished her degree the opportunities she hoped for had disappeared: "the war was over, and she could find no opening for a woman engineer."[92] First she fell back on a position training and directing computers for the turbine engineering department at General Electric. However, she was dissatisfied with computing, and so she took a job as professor of physics at Constantinople (later Istanbul) Woman's College. Like the settlement houses, Istanbul Woman's College and other missionary-run colleges for women were part of the women's reform network.[93] That network thus provided Clarke with a job and a chance to prove herself at a key point in her career. When she returned to the United States in 1922 she was able to get a job at General Electric as an engineer, and she worked there until the late 1940s. In 1946 she took a position as professor of electrical engineering at the University of Texas, where she taught until 1956. She published many professional papers, made significant contributions to electrical engineering theory, and wrote a major textbook.[94] Women's issues did not play a large role in Clarke's work, but the women's reform network provided a job opportunity at a key point in her career.

These examples of women in various fields show the success of difference feminism: the important role of the women's reform movement in transforming engineering. I draw two conclusions. Women working in fields related to engineering found the women's reform movement an essential source of career motivation and opportunities, and therefore a striking number of these women pushed reform agendas in their work. Robyn Muncy says of pioneer social workers: "For this second generation of educated women, commitment to reform opened some of the few avenues to professional growth."[95] Women engineers, though in a very different position because of their radical isolation in their own profession, seem to have found a similar pattern. Second, women saw themselves as women to have a special responsibility to reduce the human cost of uncontrolled capitalism, though they defined this in different ways. Their reform efforts therefore challenged the practices of engineering, and they were successful in introducing many new regulations and concerns. Through the middle part of the century women's clubs and organizations certainly continued to be involved in civic improvement projects of all sorts, though women became less visible as the government took over more and more of the work they had pioneered.

<A> **The Second Feminist Movement**

In the second feminist movement of the 1970s difference- and affirmative-action feminism stood in a very different relationship to each other, and that shaped a very different pattern of effects on engineering. Where the second feminist movement challenged technology it often did so from the perspective of a new kind of difference feminism that focused its analysis on the level of assumptions rather than on the level of practices. These challenges had little effect on practitioners in the field, who accepted at most equal-rights feminism. Second wave

feminism's emphasis on equal rights led to more opportunities for women in engineering, but women engineers did not find feminism a source of special job opportunities for women the way the reform movement had been in the earlier period. I want to focus here on the impact of second-wave feminism on engineering, and look for similarities and dissimilarities between its influence and that of the earlier women's reform movement.

<B> Feminist Theory

While second-wave feminism centered its political action on equal rights, difference feminism quickly became important in feminist theory. These approaches had some roots in the earlier reform arguments, though the new feminist theorists rejected the old approaches. Some women, like Rachel Carson, bridged the period between the reform tradition and a new, more radical critique of a world based on money, power, and technology.[96] However, in making that new critique second-wave difference feminists wanted to go much further than the reform tradition. They criticized not just the organization of production but the relationship between human beings and nature.

Early second-wave feminist theory did not make technology a primary issue, but over time some feminist theorists came to see technology as central to the workings of patriarchy. Carolyn Merchant's 1980 book *The Death of Nature* perhaps made the strongest early argument, though she drew her material more from the history of science than from the history of technology. Merchant examined "the formation of a world-view and a science that, by reconceptualizing reality as a machine rather than as a living organism, sanctioned the domination of both women and nature."[97] This, together with Lynn White's argument that Christianity led to the exploitation of nature, gave rise to theories that saw the rise of science and

technology as closely interwoven with the subjugation of women.[98] According to this approach women represented an alternative set of values to a patriarchal system based on the exploitation of nature, women, and other groups given second-class status. However, this approach made many second-wave feminists uncomfortable because it separated women from the basis of power in society as it was and is.

These ideas saw more development by ecofeminists, particularly Christian ecofeminists, than by scholars in the social studies of technology.[99] The conservation movement had been in many ways conservative, while the new environmental movement critiqued industrial capitalism much more directly. The feminist and environmental movements of the 1970s borrowed from each other, though their theoretical interconnections proved controversial. Some women argued that women must take the lead in abandoning patriarchal values and rediscovering women's special relationship with nature.[100] Others asserted that any argument based on women's difference would consign women to inequality and argued instead that the hierarchical dualism between nature and culture should be questioned in the same ways that feminists had questioned the dualism between men and women.[101] On the whole, ecofeminists and feminists in the environmental movement tended to image technology, particularly big, science-based technology, as male exploitation.

A few feminist sociologists pursued the idea that engineering has a traditional association with masculine values into a more specific critique of engineering. Sally Hacker argued that mind/body dualism was particularly strong in the culture of engineering, and therefore technical skills were constructed as the opposite of skills of nurturance and responsiveness.[102] Hacker leaned in the direction of the idea that engineering would be improved by an injection of women's values, while another theorist, Judy Wajcman, leaned towards the perspective that the

masculine character of engineering was simply a strategy to keep women out of power. Wajcman pointed out that the definition of what is masculine changes to meet the needs of men, for example sometimes privileging physical force and sometimes intellectual rationality. She concluded that "No matter how masculinity is defined according to this ever-adaptable ideology, it always constructs women as ill-suited to technological pursuits."[103] A study conducted in 1986 and published in 1991 by Gregg Robinson and Judith McIlwee looked for this in practice, focusing on the idea that the culture of engineering privileges masculinity. They concluded that women engineers had more success in workplaces where engineers had less power because in situations dominated by engineers, workplace culture "equates professional competence with 'masculinity.'"[104]

These critiques had little impact inside engineering because feminist practitioners did not gain recognition and influence. Searching on the word feminism in the engineering literature turns up two pockets of feminist theory in fields somewhat on the edge of engineering. In computer science feminists pointed out how education is gendered and began to raise other issues.[105] In the area of reproductive technology in particular and medical ethics more generally and extensive feminist literature did develop.[106] In both cases scholars from other fields were usually the first to raise feminist arguments, not engineers and other practitioners, but feminist analysis had significant impacts in each field. However, this process has not taken place in more mainstream engineering.

In mainstream engineering, discussion of feminism has been watered down into a few positive statements about the possible contributions of women. Samuel Florman established himself as a spokesperson for engineering in the world of public culture with the 1976 publication of his book *The Existential Pleasures of Engineering*.[107] He wrote an article in

Harpers in 1978 in which he argued that "talented young women were avoiding engineering because they perceived other professions as a more direct route to political power…. if you are smart enough to be an engineer, you're too smart to be an engineer."[108] By the 1986 publication of *The Civilized Engineer*, Florman had switched strategies and was writing about the "fresh and valuable elements" women could bring to the profession, particularly a more humanistic approach.[109] One of Florman's major theses is that humanistically educated engineers are more creative, but women engineering students not surprisingly feel nervous about his argument for difference.[110] Sometimes when engineers give speeches about the future of engineering they mention in passing the argument that women tend to have skills such as working with others and integrating diverse information that fit new trends in engineering work,[111] but there is little evidence that this rhetoric has led to any advantage for women in hiring and promotion.[112]

fit in a little of the earlier material here!

Despite the limited interest of practitioners in the feminist critique of the gendered culture of engineering, some sociologists have tried to determine whether women do engineering differently or whether engineering might be different if it were less identified with traditionally masculine values. The evidence of women bringing any kind of new ideas into engineering is mixed, at best. A 1986 study asked women engineers in interviews about "engineers' attitudes to technological development and change, to see how far women who have been socialized into a masculine profession adopt masculine value systems and how far they retain female value systems, bringing a different perspective to traditionally masculine work." The authors found very little questioning of definitions of progress, though they found some notable idealism among

the women engineers they interviewed. They concluded that when women reached a critical mass in the workplace it would be more possible to raise gender issues.[113]

In a study published in 1992, Knut Sørensen sought a broader empirical answer to the question of whether women do technology differently. While his subjects were Norwegian women and men and his workplace sample included both scientists and engineers working in R&D, his analysis is valuable for its careful evaluation of feminist arguments about difference. Sørensen carefully avoids claiming that women are essentially different, but he argues that women have different cultural resources that they may bring to a field:

> In their perception of important challenges to R&D, women are more inclined to include reproductive considerations; they have a caring, other-oriented relationship to nature and to people, an integrated, more holistic and less hierarchical world-view; a less competitive way of relating to colleagues and a greater affinity to users; or generally—to use Hilary Rose's elegant metaphor—an ability to bring together the knowledges of hand, brain and heart. The resulting ideal type is to be juxtaposed to the similarly stereotyped 'masculine counter-values': domination of nature, objectivation of research, competitiveness, acceptance of authority, and the like.

Sørensen's results suggest that women engineering students are more likely than men to claim "caring values." However, these differences did not show up in the work norms of his sample of young researchers, suggesting that socialization reduces differences by the time women finish their schooling. Nonetheless, Sørensen suggests that women in R&D find opportunities to use

their values in choosing their field and their research problems, pointing to the differences in the percentage of women in different fields of engineering.[114] There is some evidence that the same patterns hold in the United States; my own survey of students in a class for freshman engineers found women students much more likely than men students to believe that social issues are important in engineering.[115] However, these studies examine only stated values, not behavior. A 1996 study of women managers showed that even when both women and men paid lip service to ideas of women's management style, successful women tended to follow male styles.[116]

Feminist theory suggests the possibility that women might bring new ideas and approaches to engineering, as they did in the earlier women's reform movement, but there is little evidence that this possibility has been realized. It isn't simply that the number of women engineers must reach a critical mass before they will have a significant impact on engineering, since the women's reform movement had considerable impact on engineering at a time when the proportion of women engineers was even smaller. Perhaps the problem has been that feminist critiques of technology rejected such fundamental assumptions of the field that it seemed impossible to incorporate them into engineering practice. I suspect, however, that the new ideas of the reformers in the early twentieth century seemed almost as radical at the time. Just as the earlier women's reform movement led women like Lillian Gilbreth to innovative and influential new approaches, in many fields feminism has led women to ask new questions that scholars in that field found compelling. However, that has happened very little in engineering. Occasional articles in liberal journals, such as one entitled "Want Your Machine to Work? Get a Woman to Design It," have suggested the possibility of similar patterns in engineering, but little has come of it.[117]

<B> Women Engineers

The vast majority of the literature on women and engineering deals with the small number of women in engineering and with how more women might be encouraged to study engineering. This enterprise involves equal-rights feminism, since it involves women working for equality, though many participants are uncomfortable with the word "feminism." Promoters of women in engineering have almost steered away from the broader feminist critique of engineering based on difference feminism. I want to examine the advantages and disadvantages of equal-rights feminism in creating opportunities for women in engineering, compared to the pattern of opportunities created by difference feminism in the first half of the twentieth century.

The idea that women should be encouraged to study science and engineering developed before the second wave of feminism. New job opportunities for women in World War II gave some women a start, but women were almost always limited to low-level jobs. The primary motive for a change in attitudes during the war and for the continuation of some programs after the war was not feminism but worries about a shortage of "manpower" for wartime and Cold War projects. [118] Women studied engineering in somewhat larger numbers after the war, though their percentage did not go up because the number of men was growing just as rapidly. One woman who studied engineering immediately after the war said that women flooded to engineering schools, but they found when they graduated that most industries would not hire women. She made a career in the Air Force instead.[119] The Civil Rights Act of 1964 outlawed sex discrimination in many areas (though not education), but without a political movement sponsoring challenges under the new law it had little initial effect.[120]

Despite the slow change in the proportion of women, attitudes were changing in the 1950s and 1960s, as Margaret Rossiter has shown. In 1954 the Women's Bureau of the U.S.

Department of Labor published a bulletin on *Employment Opportunities for Women in Professional Engineering.* Unlike the situation in most fields of science, women engineers did not find opportunities to be better in government and non-profit institutions than in industry in the 1950s; women made up 0.5% of the engineers in industry in 1956-8.[121] Rossiter argues that women's associations were only a partial palliative, but given the lack of visibility of women engineers, the founding of the Society of Women Engineers in 1950 represented a significant step forward. By 1958 the society had 510 members, which suggests at least that women felt a need for such a group.[122] These efforts led to a significant increase in the number of women engineers, but since the number of men continued to rise and women were often excluded or limited by quotas, there was little change in the proportion of women.[123] A 1965 analysis of the lack of women engineers focused on the problems of overt discrimination.[124]

The percentage of women in engineering started to increase noticeably in the 1970s and became significant in the 1980s, in part because of changes within engineering. In the period from 1968 to 1972 women scientists and engineers began to talk about fairness and the need for change.[125] A major slump in engineering jobs occurred in the early 1970s because of the end of the Apollo program and cuts in military research and development. The number of young white men choosing to study engineering dropped in response, and engineering schools recruited women and minorities to keep up student numbers and quality.[126] Federally mandated affirmative action began to make a difference in industries that relied heavily on government contracts; in 1970 a woman engineer was told by many companies that they did not hire women except as secretaries, while in 1974 at least some women engineering graduates found themselves in demand.[127] Organizations also began to consider the issue of women engineers: the American

Society of Engineering Education formed a Task Force on Women in 1974 (later renamed the Committee on Women in Engineering).[128]

The broader feminist movement was probably at least as substantial an influence as action by women engineers. Feminists fought for laws and regulations against the discrimination that had limited or cut off many women's careers. They filed lawsuits against discrimination under various laws and executive orders and publicized both positive results and the slowness of change.[129] They fought for tougher laws, and won passage of the Equal Employment Opportunity Act of 1972 and Title IX that same year. They worked for affirmative action programs as a method of remedying a past pattern of discrimination, and for a period from the mid 1970s to the mid 1980s such programs made a significant difference for women in universities and in industries heavily dependent on government contracts.[130] Feminism also changed the broader culture. A significant number of women university students in the 1970s took from feminism the attitude that they would prove that women could do anything, and with the help of affirmative action they were able to chip away at the barriers to women's participation in engineering.

By the late 1970s and early 1980s women felt they had made progress. While women engineers rarely chose to take radical stances, the broad social impact of feminism gave many of them more confidence that they had the right to participate and more concern about helping other women. At least some male engineering professors became concerned about improving opportunities for women, particularly men who saw their own daughters struggling to break into the professions. A classroom climate hostile to women can be found to some extent in engineering classes to this day, but by the early 1980s affirmative action and the increasing number of women had broken through many of the more obvious barriers (such as the lack of "ladies rooms").[131] Feminism had led to more jobs for women in engineering not by creating

special opportunities for women, as the women's reform movement did in the earlier period, but by winning legal and administrative changes that required more equal treatment of women.

It quickly became clear that providing equal opportunity as mandated by law was not by itself enough to bring women into engineering in large numbers. By the early 1980s, analysts tended to assume that discrimination was no longer a significant problem, even though subtle prejudice was still common in engineering, sometimes much to the surprise of young women who did not expect awkwardness just because they were women.[132] Rather than take on subtle prejudice head on, studies of how to encourage more women to study engineering came to emphasize networking, mentoring, and career development programs. Organizations such as the Women in Engineering: Program Advocates Network, the Society for Women Engineers, and the Women in Engineering Program of the Institute of Electrical and Electronic Engineers provided information to encourage young girls to consider careers in engineering, mentors for women undergraduates, and networking for working women.[133] These programs aimed mostly at making women feel more comfortable in engineering, or at least giving them someone to turn to for advice and comfort when they felt uncomfortable.

The feminist critique of the masculine style of engineering has received some attention within this effort, but authors who pick up the idea tend to assume that women should adapt to the male style. Some studies have shown that older firms and older industries tend to have stronger old-boy networks and climates in which women feel more isolated.[134] However, Robinson and McIlwee's study of the culture of engineering describes what they call a "technical locker room" style in young high-tech companies, in which women feel very uncomfortable. They contrast this with more bureaucratic firms in which women fare better both because of affirmative action and because engineers have less decision-making power in those firms.

Robinson and McIlwee conclude: “Men are not better engineers, but they are better at *appearing* to be better engineers in a *male-defined* way.”[135] An article by an engineering graduate student that borrows heavily from this work restates the message in a way that puts the responsibility on women: “In workplaces where engineers hold power, a culture of engineering based on a male style of interaction prevails. Women fail to understand the unwritten rules of conduct and, as a result, fail to effectively promote their strengths.”[136] Or, in the words of an article written by women and published in *Science*: if women are isolated they “may be slow to learn the ‘unwritten rules’ that lead to corporate success.”[137] The Society of Women Engineers even published an article in 1993 on “Learning to Compete with Women.”[138] The alternative view, that “there is little reason to believe that existing cultural norms are necessary to the pursuit of excellence in science and engineering,” has received little attention.[139]

While progress has been slow for women in engineering overall, there is considerable variation among subfields. The fields of engineering that have the highest proportion of women today are bioengineering and environmental engineering. In my own institution, this year women make up more than 50% of the incoming graduate students in environmental engineering.[140] The following figures show the percentage of bachelor’s degrees going to women in some major fields of engineering in 1983 and 1993.[141] The column for “field size” show the change in the total number of degrees granted in that field while the column for “number of women” shows the change in the number (not percentage) of women receiving degrees in that field.

[Table 8.1]

For example, the percentage of degrees in chemical engineering going to women increased, but the total number of degrees in chemical engineering declined sharply and even with an increase in percentage the number of women receiving degrees in that field declined. A finer division is

required to draw many conclusions, but chemical engineering probably includes most students aiming at careers in environmental engineering, and industrial and management engineering is the field pioneered by Lillian Gilbreth. One analysis of such figures argues that young women often do not want to be seen as masculine and they perceive fields like chemical engineering to be less masculine than, for example, mechanical engineering.[142] However, the difference could also be explained by the argument that young women are more likely than young men to be interested in fields that they see as more involved with people and as more idealistic.

Women have found more job opportunities in engineering, according to a pattern quite different from the early twentieth century. In the earlier period women used the women's reform network to develop some job opportunities particularly for women. Second-wave feminism fought instead for women to compete equally for the same jobs as men. This approach has been successful to an extent that would have been beyond the wildest dreams of women with technical expertise in the early twentieth century. However, because this approach was based on an argument from equality, it has made any discussion of how women might be different seem very risky.[143] It has therefore been very difficult for women to use the feminist critique of engineering to reform engineering. In the end, if the difference feminism makes is defined by whether increasing participation by women has changed the engineering profession, it is simply too early to answer the question.

<A> **Conclusions**

Feminism has the most impact on a field when it opens opportunities for women, either through jobs or by providing a source for innovative ideas. Early-twentieth-century difference feminism clearly opened opportunities for middle-class women to deal with issues relating to

factories and municipal engineering and to make a difference as reformers, though very few women made it into the mainstream of engineering. In the late twentieth century, equal-rights feminism won women job opportunities in mainstream engineering, but because this approach claimed that women were the same as men, the potential opportunities for innovation provided by feminist theory in general and difference feminism in particular were difficult to realize.

The contribution of reformers both inside and outside engineering is a critical part of the story of the impact of feminism. Florman writes: "Naturally, as our technology becomes more advanced and our society becomes more complex, our rules and regulations become more numerous and our means of enforcing them more varied."[144] What I have shown, I hope, is that this is not a natural phenomenon, but rather the outcome of a hard battle led and fought in large part by women reformers. The women's reform tradition led women to the belief that in their public activities they should seek to make the world a better place, and particularly to protect the weak. Though they did not often became radicals, women tended to stand at least slightly outside the mainstream of industrial capitalism and to seek to humanize it.

However, women did not form an interest group separated from engineering and technical expertise. Women reformers used technical expertise and alliances with experts, and women experts found career opportunities and made creative contributions to their fields because of their reform beliefs. Women engineers could try to be accepted as equal in the culture of engineering, and some did so, but women found themselves more welcome in the reform enterprises. Precisely because they did something different, some women with reform interests made particularly significant contributions to technical fields.

Such creative travel over the boundary between reform and professionalism proved much more difficult for second-wave feminists because of the success of equal-rights feminism.

Women fought for and won job opportunities in engineering, and as they found themselves less marginalized they had less need for the kind of special career opportunities for women that reform had provided. On the other hand, women who followed a strategy of equal-rights feminism could not use reform commitments or being different or feminist theory as an asset on the job and a source of creativity. Perhaps the clustering of women in certain fields of engineering will make that possible in the future the way clustering of women in some fields of science (such as primatology) has enabled the integration of feminist ideas into those sciences.

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Endnotes

[1] For a historical discussion of the definition of feminism and an argument for defining feminism narrowly, see Nancy Cott, *The Grounding of Modern Feminism* (New Haven, CT: Yale University Press, 1987), 3-10.

[2] For one philosophical analysis of the complexities of this idea see Rita Felski, "The Doxa of Difference," *Signs* 23 (1997): 1-22.

[3] I see this particularly in my unpublished research on women scientists at Mount Holyoke College. Historians of women in medicine have suggested a shift in the early twentieth century from an argument about women's special contribution to medicine to an emphasis on participating in the mainstream that seems to me to be a quiet equal-rights feminism. See for example: Regina Markell Morantz-Sanchez, *Sympathy and Science: Women Physicians in American Medicine* (New York: Oxford University Press, 1985).

[4] See the contributions in this volume by Cowan, Oldenzeil, and Purcell. For an introduction to broader approaches to gender and technology, see the special theme issue on "Gender Analysis and the History of Technology," ed. Nina E. Lerman, Arwen Palmer Mohun, and Ruth Oldenzeil, *Technology and Culture* 38 (1997):1-231, and also Judith A. McGaw, "Women and the History of American Technology," *Signs* 7 (1982): 798-828. An extensive bibliography can be found in Cynthia Gay Bindocci, *Women and Technology: An Annotated Bibliography* (New York: Garland, 1993).

[5] Samual C. Florman, *The Civilized Engineer* (New York: St. Martin's Press, 1987), 88.

[6] For a discussion of the issue of public culture see Paula Baker, "The Domestication of Politics: Women and American Political Society, 1780-1920," in *American Historical Review* 89 (1984): 620-47; Kathryn Kish Sklar, *Florence Kelley and the Nation's Work: The Rise of Women's Political Culture, 1830-1900* (New Haven, CT: Yale University Press, 1995), and, for an international comparison, Seth Koven and Sonya Michel, eds., *Mothers of a New World: Maternalist Politics and the Origins of Welfare States* (New York: Routledge, 1993).

[7] For the argument that career opportunities are central to the story I am indebted to Robyn Muncy, "Gender and Professionalization in the Origins of the U.S. Welfare State: The Careers of Sophonisba Breckinridge and Edith Abbott, 1890-1935," *Journal of Policy History* 2 (1990): 290-315.

[8] See Cott, *Grounding of Modern Feminism*.

[9] For the nineteenth century background see for example Barbara Epstein, *The Politics of Domesticity* (Middletown, CT: Wesleyan University Press, 1981); Anne Firor Scott, *Natural Allies: Women's Associations in American History* (Urbana, IL: Univ. of Illinois Press 1991), and Aileen S. Kraditor, *The Ideas of the Woman Suffrage Movement, 1890-1920* (New York: W. W. Norton, [1965] 1981).

[10] See, e.g., Scott, *Natural Allies*.

[11] Chafe goes on to explain in parentheses: "Some supporters of these efforts were men, to be sure, but men whose attitudes had largely been shaped by experience in female-centered institutions like the settlement house." William H. Chafe, "Women's History and Political History: Some Thoughts on Progressivism and the New Deal," in *Visible Women: New Essays on*

American Activism, ed. Nancy A. Hewitt and Suzanne Lebsock (Urbana, IL: Univ. of Illinois Press, 1993), 105.

[12] Cott, *The Grounding of Modern Feminism*, 88. For discussion of the large role of women's groups in gaining enforcement of pure food laws see Mary Ritter Beard, *Woman's Work in Municipalities* (New York: D. Appleton and Co., 1916), 70-78.

[13] Florman, *The Civilized Engineer*, 89.

[14] Sybil Lipschultz, "Hours and Wages: The Gendering of Labor Standards in America," *Journal of Women's History* 8 (1996): 114-36.

[15] Sklar, *Florence Kelley and the Nation's Work, xv.*

[16] Kathyrn Kish Sklar, "Two Political Cultures in the Progressive Era: The National Consumers' League and the American Association for Labor Legislation" in *U.S. History as Women's History: New Feminist Essays*, ed. Linda Kerber, Alice Kessler-Harris, and Kathryn Kish Sklar (Chapel Hill: Univ. of North Carolina Press, 1995), 61-62.

[17] Barbara Sicherman, "Working it Out: Gender, Profession, and Reform in the Career of Alice Hamilton," in *Gender, Class, Race and Reform in the Progressive Era*, ed. Noralee Frankel and Nancy S. Dye (Lexington: Univeristy Press of Kentucky, 1991), 128.

[18] Scott, *Natural Allies*, 156. Scott's chapter on municipal housekeeping suggests that women had a large role in improvements in urban infrastructure.

[19] Muncy, "Gender and Professionalization in the Origins of the U.S. Welfare State," 290.

[20] Cott, *Grounding of Modern Feminism*, ch. 3.

[21] Ibid., 97.

[22] Scott suggests that "Perhaps women had an advantage when it came to understanding the negative consequences of what were generally seen as the great positive accomplishments of the urban-industrial revolution" because they were insulated from the competition of the marketplace. Scott, *Natural Allies*, 3. For further analysis of these issues see Sklar, "Two Political Cultures in the Progressive Era."

[23] Morantz-Sanchez, *Sympathy and Science*, 282-89.

[24] Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Sciences* (Chapel Hill: The University of North Carolina Press, 1997).

[25] Ibid., 36.

[26] For the history of women's medical colleges and the tension between separatism and integration for women in medicine see Morantz-Sanchez, *Sympathy and Science.*

[27] See Jane Addams, *Twenty Years at Hull-House* (New York: Macmillan, 1911), 202. For a few years Kelley even held a state government position as chief factory inspector, enforcing the new law. Her appointment was controversial and her work difficult. Although she left Hull House in 1899, Kelley continued to play a large role in efforts to reform industry as head of the National Consumers League, an organization that encouraged women consumers to purchase products from businesses with fair labor practices and worked for regulation. On Kelley, see Sklar, *Florence Kelley and the Nation's Work*, chapters 10 and 11; Sicherman, *Alice Hamilton*, 130; Sklar, "Two Political Cultures in the Progressive Era", 43.

[28] A law restricting hours for men was allowed in 1917 on the grounds that it was a legitimate health regulation. Wex S. Malone, Marcus L. Plant, and Joseph W. Little, *Cases and Materials*

on Workers' Compensation and Employment Rights (St. Paul, MN: West Publishing Co., 1980), 574-75. Lipschultz, "Hours and Wages," 118-19, 122-24.

[29] Sicherman, *Alice Hamilton,* 153.

[30] Ibid., 153-54.

[31] Ibid., 155-57. In 1909 Hamilton had actually declined a position investigating phosphorus poisoning in the match industry, which was the first case where industrial processes were regulated by the federal government to prevent disease.

[32] Ibid., 159, 180, 239.

[33] Ibid., 209-10.

[34] See for example Molly Ladd-Taylor, "Hull House Goes to Washington: Women and the Children's Bureau," in *Gender, Class, Race and Reform in the Progressive Era*, 110-26.

[35] Malone et. al., *Cases and Materials on Workers' Compensation and Employment Rights*, 579. The Supreme Court did not change its position about minimum wage laws until 1936.

[36] Sicherman, *Alice Hamilton,* 280.

[37] Ibid., 3.

[38] Quoted in Sicherman, *Alice Hamilton,* 315. For more on this story see Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910-1935* (Chapel Hill, NC: University of North Carolina Press, 1997).

[39] For the idea that women reformers bridged the conservative period between the progressives and the New Deal see Chafe, "Women's History and Political History," 109. For Hamilton's experience see Sicherman, *Alice Hamilton,* 357.

[40] Felton Gibbons and Deborah Strom, *Neighbors to the Birds: A History of Birdwatching in America* (New York: W. W. Norton, 1988), 176.

[41] Stephen Fox, *The American Conservation Movement: John Muir and His Legacy* (Madison, WI: University of Wisconsin Press, 1985), first published as *John Muir and His Legacy: The American Conservation Movement* (New York: Little Brown and Co., 1981), 341-42.

[42] Carolyn Merchant, *Earthcare: Women and the Environment* (New York: Routledge, 1995), 123-24. The issue of hat feathers involved Audubon societies and women's clubs for many years, but in 1913 a new Tariff Act outlawed the importation of wild bird feathers (Ibid., 127).

[43] Fox, *The American Conservation Movement*, 342. See also Gibbons and Strom, *Neighbors to the Birds*, chapter 9, 175-89.

[44] Merchant, *Earthcare*, 111.

[45] Ibid., 112.

[46] Ibid., 110-20.

[47] Quoted in Fox, *The American Conservation Movement*, 343.

[48] Merchant, *Earthcare*, 122.

[49] Fox, *The American Conservation Movement*, 345; see also Merchant, *Earthcare*, 128-30.

[50] Though not less plentiful—the General Federation of Women's Clubs continued to be active in conservation issues and in 1915 women made up about half the National Audubon Society membership (Ibid., 136).

[51] Fox, *The American Conservation Movement*, 175-76.

[52] Ibid., 202-3.

[53] Quoted in ibid., 344.

[54] See for example Scott, *Natural Allies*, chapter 6, "Inventing 'Progressivism': Municipal Housekeeping," and particularly 143; and Suellen M. Hoy, "'Municipal Housekeeping': The Role of Women in Improving Urban Sanitation Practices, 1880-1917," in *Pollution and Reform in American Cities, 1870-1930*, ed. Martin V. Melosi (Austin, TX: University of Texas Press, 1980), 173-98.

[55] Quoted in Beard, *Woman's Work in Municipalities*, 74.

[56] Beard, *Woman's Work in Municipalities*, 86.

[57] Sarah Stage, "Ellen Richards and the Social Significance of the Home Economics Movement," in *Rethinking Home Economics: Women and the History of a Profession*, ed. Sarah Stage and Virginia B. Vincenti (Ithaca, NY: Cornell University Press, 1997), 17-33.

[58] Stage, "Ellen Richards," 21. See also Margaret W. Rossiter, *Women Scientists in America: Struggles and Strategies to 1940* (Baltimore: Johns Hopkins University Press, 1982), 30.

[59] Stage, "Ellen Richards," 22-24, Rossiter, *Women Scientists in America* , 68. For details on Richards work on food and water purity see: Hoy, "'Municipal Housekeeping'," 179-81.

[60] Stage, "Ellen Richards," 24-25.

[61] Ibid., 27.

[62] Quoted in Keturah E. Baldwin, *The AHEA Saga* (Washington, D.C.: American Home Economics Association, 1949), 21. The statement of purpose was changed in 1930 to: "the development and promotion of standards of home living that will be satisfying to the individual and profitable to society." The home economics movement took a conservative turn around 1920 and separated itself from municipal housekeeping and the women's reform movement. Baldwin, *The AHEA Saga*, 25-6; Stage, "Ellen Richards," 32.

[63] Ellen H. Richards, *Conservation by Sanitation: Air and Water Supply, Disposal of Waste (Including a Laboratory Guide for Sanitary Engineers)* (New York: John Wiley & Sons, 1911), *v.* This book also has an interesting final chapter on the training and work of the engineer.

[64] O'Ryan Rickard, *A Just Verdict: The Life of Caroline Bartlett Crane* (Kalamazoo, MI: New Issues Press of Western Michigan University, 1994), 45-98.

[65] Ibid., 7, 99-142.

[66] Ibid., 161-218, 233; Hoy, "'Municipal Housekeeping'," 184-88.

[67] Beard, *Woman's Work in Municipalities*, 87.

[68] Rickard, *A Just Verdict*, 190.

[69] For an analysis of gender issues in Crane's work see: Linda J. Rynbrandt, *Caroline Bartlett Crane and Progressive Reform: Social Housekeeping as Sociology* (New York: Garland Publishing, 1998).

[70] For the reform role of municipal engineers see Stanley K. Schultz and Clay McShane, "Pollution and Political Reform in Urban America: The Role of Municipal Engineers, 1840-1920," in *Pollution and Reform in American Cities, 1870-1930*, ed. Martin V. Melosi (Austin, TX: Univ. of Texas Press, 1980), 155-72; and Martin V. Melosi, *Garbage in the Cities: Refuse, Reform, and the Environment, 1880-1980* (College Station, TX: Texas A&M University Press, 1981), chapter 3.

[71] Hoy, "'Municipal Housekeeping'," 188, 191.

[72] Beard, *Woman's Work in Municipalities*, 90.

[73] On industrial psychology, see Laura L. Koppes, "American Female Pioneers of Industrial and Organizational Psychology During the Early Years," *Journal of Applied Psychology* 82 (1997): 500-15.

[74] For a detailed analysis of this transition see Laurel Graham's excellent biography, *Managing on her Own: Dr. Lillian Gilbreth and Women's Work in the Interwar Era* (Norcross, GA: Engineering and Management Press, 1998), chapter 3. The impulse she and her husband shared to rationalize their home was chronicled by two of their children in Frank B. Gilbreth Jr. and Ernestine Gilbreth Carey, *Cheaper by the Dozen* (New York: T. Y. Crowell, 1948).

[75] Laurel Graham, "Beyond Manipulation: Lillian Gilbreth's Industrial Psychology and the Governmentality of Women Consumers," *The Sociological Quarterly* 38 (1997): 539-66.

[76] Martha Moore Trescott, "Lillian Moller Gilbreth and the Founding of Modern Industrial Engineering," in *Machina ex Dea: Feminist Perspectives on Technology*, ed. Joan Rothschild (New York: Pergamon Press, 1983), 26.

[77] Sherry E. Sullivan, "Management's Unsung Theorist: An Examination of the Works of Lillian M. Gilbreth," *Biography* 18 (1995): 33.

[78] Trescott, "Lillian Moller Gilbreth," 32. This contribution is discussed in more detail in Graham, *Managing on her Own*, chapter 2.

[79]This interest probably stemmed not just from the needs of war but from Frank Gilbreth's experience of temporary paralysis from rheumatism during the war. J. Micheal Gotcher, "Assisting the Handicapped: The Pioneering Efforts of Frank and Lillian Gilbreth," *Journal of Management* 18 (1992): 5-14. The books were: Edna Yost and Lillian Gilbreth, *Normal Lives for*

the Disabled (New York: Macmillan, 1944) and *Straight Talk for the Disabled Veteran* (New York: Public Affairs Committee, 1945).

[80] Trescott, "Lillian Moller Gilbreth and the Founding of Modern Industrial Engineering," 30. In the 1920s, Gilbreth also did a major study of menstruation and the sanitary pad, see ibid. 31.

[81] Lillian M. Gilbreth, *As I Remember* (Norcross, GA: Engineering and Management Press, 1998), 144. Laurel Graham, "Beyond Manipulation."

[82] Alice C. Goff, *Women Can Be Engineers* (Youngstown, OH: 1946). Goff does not tell her own story beyond saying that she is a structural engineer who designs reinforced concrete buildings (*iv*).

[83] In 1955 22,589 persons received bachelor's degrees in engineering, of whom 62 were women. In that year, the percentage of bachelors degrees going to women was 3.8% in physics, compared to 0.27% in engineering. *Science and Engineering Degrees: 1950-86: A Source Book*. National Science Foundation, Surveys of Science Resource Series, NSF 88-323, 1988.

[84] 1910 and 1940 figures are percentage of women enrolled in engineering programs, not B.A. degrees. Sources for table: Report of the Commissioner of Education for the year ended June 30, 1910, vol. II, chapter XXI Universities, Colleges and Technological Schools (Washington, D.C.: GPO, 1911); Department of the Interior, *Bureau of Education Bulletin* 1923, No. 29, Biennial Survey of Education 1918-20, Statistics, chapter IV Statistics of Universities, Colleges and Professional Schools 1919-1920 (Washington: GPO 1923); Department of the Interior, *Office of Education Bulletin* 1931, No. 20, Biennial Survey of Education 1928-1930, vol. II, chapter IV, Statistics of Universities, Colleges, and Professional Schools 1929-30 (Washington: GPO 1932); Federal Security Agency, U.S. Office of Education, *Biennial Surveys of Education in the US*

1938-40 and 1940-42, vol. II, chapter IV, Statistics of Higher Education 1939-40 and 1941-42 (Washington, D.C.: GPO, 1944); *Science and Engineering Degrees: 1950-86: A Source Book* (Washington, D.C.: National Science Foundation, Surveys of Science Resource Series, NSF 88-323, 1988); Susan T. Hill , "Science and Engineering Degrees Awarded to Women Increase Overall, but Decline in Several Fields" NSF Data Brief, Directorate for Social, Behavioral and Economic Sciences, National Science Foundation, NSF 97-326, November 7, 1997, http://www.nsf.gov/sbe/srs/databrf/sdb97326.htm.

[85] See Monte A. Calvert, *The Mechanical Engineer in America: 1830-1910* (Baltimore: Johns Hopkins Univ. Press, 1967).

[86] Earle D. Ross, *Democracy's College: The Land-Grant Movement in the Formative Stage* (Ames: Iowa State College Press, 1942).

[87] Martha Moore Trescott, "Women in the Intellectual Development of Engineering: A Study in Persistence and Systems Thought," in *Women of Science: Righting the Record*, ed. G. Kass-Simon and Patricia Farnes (Bloomington, IN: Indiana Univ. Press, 1990), 168-76. Some of the women Trescott includes are: Emily Roebling (1844-1903) sometimes gets credit as the first woman field engineer for directing the construction of the Brooklyn Bridge after her husband was disabled. She went on to earn a law degree and work for women's suffrage. Julia Brainerd Hall (1859-1925) studied chemistry at Oberlin and worked closely with her brother in the 1880s in the invention of electrolytic separation of aluminum. Kate Gleason (1865-1933) attended Cornell for a year in the 1880s and became "world famous for her original design of worm gears" working for a firm founded by her father. Bertha Lamme (1869-1954), graduated from Ohio State with a degree in mechanical engineering "with an option in electricity" in 1893, and worked with

her brother at Westinghouse until she married a colleague in 1905. An interesting story not covered by Trescott is Nora Barney, who received a degree in Civil Engineering from Cornell in 1905 and worked as an engineer before and after her brief marriage to radio inventor Lee de Forest. Barney was also deeply involved in the suffrage movement. See Terry Kay Rockefeller, "Barney, Nora Stanton Blatch," in *Notable American Women: The Modern Period*, ed. Barbara Sicherman and Carol Hurd Green (Cambridge, MA: Harvard University Press, 1980), 53-55.

[88] Quoted in Martha M. Trescott, "Women Engineers in History: Profiles in Holism and Persistence," in *Women in Scientific and Engineering Professions*, ed. Violet B. Haas and Carolyn C. Perrucci (Ann Arbor, MI: Univ. of Michigan Press, 1984), 184.

[89] Goff, *Women Can Be Engineers*, 5.

[90] Ibid., 66-67.

[91] Ibid., 51-55.

[92] Ibid., 55.

[93] For the women's missionary movement in general see Patricia R. Hill, *The World Their Household: The American Woman's Foreign Mission Movement and Cultural Transformation, 1870-1920* (Ann Arbor, MI: University of Michigan Press, 1985) and Dana L. Robert, *American Women in Mission: A Social History of Their Thought and Practice* (Macon, GA: Mercer University Press, 1996).

[94] Ibid. 55-64, and Trescott, " Women in the Intellectual Development of Engineering," 164-68.

[95] Muncy, "Gender and Professionalization in the Origins of the U.S. Welfare State," 297.

[96] This transition deserves much more attention than I can give here. See for example Linda Lear, *Rachel Carson: Witness for Nature* (New York: Henry Holt, 1997).

[97] Carolyn Merchant, *The Death of Nature: Women, Ecology and the Scientific Revolution* (New York: Harper and Row, 1980), *xvii*.

[98] Lynn White, Jr., *Machina Ex Deo: Essays in the Dynamism of Western Culture* (Cambridge, MIT Press, 1968). For an interesting pulling together of these ideas in new ways see David F. Noble, *A World Without Women: The Christian Clerical Culture of Western Science* (New York: Knopf, 1992).

[99] For an introduction to the connections between eco-feminism and religion see Nancy R. Howell, "Ecofeminism: What One Needs to Know," *Zygon* 32 (1997): 231-42.

[100] Merchant, *Earthcare,* 139-66.

[101] Marlene Longenecker, "Women, Ecology, and the Environment: An Introduction," *NWSA Journal* 9 (1997): 1-18.

[102] Sally L. Hacker, *"Doing it the Hard Way": Investigations of Gender and Technology* (Boston, MA: Unwin Hyman, 1990), 121-22.

[103] Judy Wajcman, *Feminism Confronts Technology* (University Park, PA: The Pennsylvania State University Press, 1991).

[104] J. Gregg Robinson and Judith S. McIlwee, "Men, Women and the Culture of Engineering," *The Sociological Quarterly* 32 (1991): 403-21, quote from 406. The authors also published a book: Judith S. McIlwee and J. Gregg Robinson, *Women in Engineering: Gender, Power, and WorkPlace Culture* (Albany: State University of New York Press, 1992).

[105] Some representative references are: Sherry Turkle, *The Second Self: Computers and the Human Spirit* (New York: Simon and Schuster, 1984); Joan Greenbaum, "The Head and the Heart: Using Gender Analysis to Study the Social Construction of Computer Systems,"

Computers & Society 20 (1990): 9-17; Ruth Perry and Lisa Greber, “Women and Computers: An Introduction,” *Signs* 16 (1990); Liesbet van Zoonen, "Feminist Theory and Information Technology" *Media, Culture and Society* 14 (1992): 9-29; Lynn Cherny and Elizabeth Reba Weise, eds., *Wired Women: Gender and New Realities in Cyberspace* (Seattle, WA: Seal Press, 1996); Nina Lykke and Rosi Braidotti, *Between Monsters, Goddesses & Cyborgs: Feminist Confrontations with Science, Medicine & Cyberspace* (New York: St. Martins Press, 1996); Thelma Estrin, “Women’s Studies and Computer Sciences, Their Intersection,” *IEEE Annals of the History of Computing* 18, no. 3 (1996): 43-46 (discussed in Mahoney, this volume); Laura DiDio, “Booth Bimbo Bingo,” *Computerworld* 46 (Nov. 17, 1997): 98.

[106] Representatives references for reproductive technologies include: Michelle Stanworth, *Reproductive Technologies: Gender, Motherhood, and Medicine* (Minneapolis, MN: University of Minnesota Press, 1987); Patricia Spallone and Deborah Lynn Steinberg, *Made to Order: The Myth of Reproductive and Genetic Progress* (Oxford, New York: Pergamon Press, 1987); Kathryn Strother Ratcliffe, ed., *Healing Technology: Feminist Perspectives* (Ann Arbor, MI: University of Michigan Press, 1989); Helen Bequaert Homes and Laura M. Purdy, eds., *Feminist Perspectives in Medical Ethics* (Bloomington, IN: University of Indiana Press, 1992); Robyn Rowland, *Living Laboratories: Women and Reproductive Technologies* (Bloomington, IN: Indiana Univ. Press, 1992); Susan M. Wolf, *Feminism and Bioethics: Beyond Reproduction* (New York: Oxford University Press, 1996); Anne Donchin and Laura Martha Purdy, *Embodying Bioethics: Recent Feminist Advances* (Lanham: Rowman and Littlefield, 1998).

[107] Samuel C. Florman, *The Existential Pleasures of Engineering* (New York: St. Martin’s Press, 1976, reprinted 1994, 1996).

[108] Florman, *The Civilized Engineer*, 215.

[109] Ibid., 216.

[110] Others have also suggested that a broader engineering education would both attract more women and improve engineering; see for example: Sharon Beder, "Towards a More Representative Engineering Education," *International Journal of Applied Engineering Education*, 5, no. 2 (1989): 173-182, http://www.uow.edu.au/arts/sts/sbeder/education2.html (1/15/00).

[111] For example, Martha W. Gilliland, "The Special Voices of Women in Engineering," *SWE: Magazine of the Society of Women Engineers* 40 (July/August 1994): 24-27.

[112] One study shows that in management, where such rhetoric has been even more common, women who get ahead tend to use a more traditional style. Judy Wajcman, "Desperately Seeking Differences: Is Management Style Gendered?" *British Journal of Industrial Relations* 34 (1996): 333-50.

[113] Ruth Carter and Gill Kirkup, "Women in Professional Engineering: The Interaction of Gendered Structures and Values," *Feminist Review* 35 (1990): 92-101.

[114] Knut H. Sørensen, "Towards a Feminized Technology? Gendered Values in the Construction of Technology," *Social Studies of Science* 22 (1992): 2-31, 22.

[115] Some suggestive U.S. data is available in Kathryn W. Linden, William K. LeBold, Kevin D. Shell and Carolyn M. Jagacinski, "Perceived Interests of Student and Professional Engineers," *U.S. Woman Engineer* 32 (May/June 1986): 21-24. My own study had a response rate of 73 out of 99 students in a history class for freshman engineers. Of the 12 women, 6 (50%) already thought that social issues were important to engineering (before beginning the course) while 6

(50%) said they learned from the course that social issues were more important to engineering than they had realized. Of 61 men, 13 (21%) said they already though social issues important, 40 (66%) said they learned that social issues were important, and 8 (13%) said that engineers should worry about the technical issues and leave the social issues to someone else. The correlation is significant at the .05% level.

[116] Wajcman, "Desperately Seeking Differences."

[117] For example: Hugh Aldersey-Williams, "Want Your Machine to Work? Get a Woman to Design It," *New Statesman* 126 (Aug. 8, 1997): 44-46. Lael Parrot, "Women and the Culture of Engineering: Society Could Benefit from More Female Engineers," *Resource: Engineering & Technology for a Sustainable World* 5 (Jan. 1998): 6-9.

[118] Margaret W. Rossiter, *Women Scientists in America: Before Affirmative Action, 1940-1972* (Baltimore, MD: Johns Hopkins University Press, 1995), esp.14-16, 55-56.

[119] Arminta Harness, speaking as part of the luncheon program in "Women in Engineering: Conference Proceedings," College of Engineering, University of Washington, November 4, 1974, 18. Another story of entering engineering after the war can be found in Theresa Snyder, "An Interview with Margaret Eller," *U.S. Woman Engineer* 39 (Mar./Apr. 1993): 19-21.

[120] Leslie A. Barber, "U.S. Women in Science and Engineering, 1960-1990: Progress Toward Equity?" *Journal of Higher Education* 66 (1995): 213-35. However, colleges and universities were exempt from the Civil Rights Act. The one field in which women found significant new opportunities was computer science, apparently because men did not realize that programming would be a significant and interesting endeavor. See for example *IEEE Annals of the History of Computing*, Special Issue on Women in Computing, Fall 1996, vol. 18, no. 3.

[121] Rossiter, *Women Scientists in America: Before Affirmative Action*, 340, 236, 259, 278-79. However, the figure for industry also includes self-employed, and it may be that larger numbers of women in that category throw off the figures. It is interesting that women were a higher percentage of engineers employed in industry than of engineering B.A.s (0.3% in 1955); this may reflect distortions in the statistics or it may reflect women with degrees in science who took jobs in engineering.

[122] Ibid., 339. For more on the history of the Society of Women Engineers see Alexis C. Swoboda, "The SWE Story," *U.S. Woman Engineer* 39 (Mar./Apr. 1993): 8-12.

[123] For a discussion of the importance of considering both changes in raw number and changes in percentage see Mariam K. Chamberlain, ed., *Women in Academe: Progress and Prospects* (New York: Russell Sage Foundation, 1988), 200-7.

[124] Jessie Bernard, "The Present Situation in the Academic World of Women Trained in Engineering," in *Women and the Scientific Professions*, ed. Jacquelyn A. Mattfeld and Carol G. Van Aken, (Cambridge: MIT Press, 1965). For an interesting contrasting story of a woman trained in science who moved into engineering see Mildred S. Dresselhaus, "Electrical Engineer," in *Women and Success: The Anatomy of Achievement*, ed. Ruth B. Kundsin,(New York: William Morrow & Co., 1974), 38-43.

[125] Rossiter, *Women Scientists in America: Before Affirmative Action*, 361. Rossiter documents the influence of feminism on key women scientists, but does not consider engineering separately.

[126] Chamberlain, *Women in Academe*, 220.

[127] Affirmative action was first included in an executive order prohibiting discrimination in the early 1960s, and sex discrimination was added to the list of prohibited forms of discrimination in

1968. Chamberlain, *Women in Academe*, 171. My example of corporate unwillingness to hire women comes from a profile of "Nance Dicciani—A Bias for Action," *U.S. Woman Engineer* 32 (Jan./Feb. 1985): 5-9. For an example of the demand for women engineers see talk by Lynn Colella Bell in "Women in Engineering: Conference Proceedings," College of Engineering, University of Washington, November 4, 1974, 14.

[128] Jane Zimmer Daniels, "Organizations, Conferences, Publications and Funding for Women in Engineering: A Historic Review," *SWE: Magazine of the Society of Women Engineers* 41 (March/April 1995): 22-26.

[129] Rossiter, 374-6 and Chamberlain, *Women in Academe*, 172-74, 181-83.

[130] For a careful definition and discussion of affirmative action see Chamberlain, *Women in Academe*, chapter 8.

[131] I write this paragraph in part from my own experience as a science student (Harvard 1977) and my impressions of the experience of a woman friend who was an engineering major. I am very serious about what engineering professors learned from their daughters; when I talked about these issues with senior engineering faculty ten years ago I frequently heard stories of their daughters' professional struggles (not necessarily in engineering). For the chilly classroom climate see: Roberta M. Hall, *The Classroom Climate: A Chilly One for Women*. Project on the Status of Education of Women, Association of American Colleges, Washington, D.C., 1982.

[132] Linda Geppert, "The Uphill Struggle: No Rose Garden for Women in Engineering," *IEEE Spectrum* 32 (May 1995): 40-50, especially 47-49. Stephen G. Brush , "Women in Science and Engineering," *American Scientist* 79 (1991): 404-19.

[133] See the web pages of these organizations for examples. WEPAN is at: http://wepan.engr.washington.edu, The Society for Women Engineers is at http://www.swe.org and IEEE Women in Engineering is at http://www.ieee.org/organizations/committee/women/ (1/15/99).

The National Academy of Engineering's Celebration of Women in Engineering is at http://www.nae.edu/nae/cwe/cwe.nsf/Homepage/NAE+Celebration+of+Women+in+Engineering?OpenDocument (1/15/00).

[134] Elizabeth Culotta, Patricia Kahn, Toomas Koppel, and Ann Gibbons, "Women Struggle to Crack the Code of Corporate Culture," *Science* 260 (Apr. 16, 1993): 389-404.

[135] Robinson and McIlwee, "Men, Woman, and the Culture of Engineering," 417.

[136] Lael Parrot, " Women and the Culture of Engineering," 7.

[137] Culotta et. al., "Women Struggle to Crack the Code of Corporate Culture."

[138] Adele Scheele, "Learning to Compete with Women," *U.S. Woman Engineer* 39 (March/April 1993): 38-39.

[139] Barber, "U.S. Women in Science and Engineering." Unfortunately, Barber's discussion of this conclusion cites examples only from science. One organization that seems to be an exception to the pattern of not trying to change the system is Catalyst, a consulting company working to advance women in business. They published a report in 1992 on "Women in Engineering: An Untapped Resource" that discusses how women engineers are subject to "intense pressure to conform to 'masculine' styles." For more information see http://www.catalystwomen.org/ (1/15/00).

[140] Personal conversation, Alan Elzerman, Aug. 18, 1998.

[141] Figures from National Science Foundation, *Women, Minorities, and Persons With Disabilities in Science and Engineering: 1996* (Washington, D.C.: NSF 96-311, Sept. 1996), appendix table 3-26.

[142] Monica Frize, "Managing Diversity," a paper written for the 1998 More than Just Numbers Conference in Vancouver and available at: http://www.carleton.ca/wise/mtjn98pap.html (1/15/00).

[143] A group of women engineers talk frankly about this in Geppert, "The Uphill Struggle," 44-46.

[144] Florman, *The Civilized Engineer,* 90.