

WOMEN AS A RESOURCE FOR THE FLEXIBILITY REQUIRED FOR HIGH TECHNOLOGY INNOVATION

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Summary

What do women scientists need to know for career advancement into senior level positions? Our declining economic conditions have been the cause for major political and technological changes. The U.S. Congress is turning toward technology to increase our competitive edge in the world. Allowing women scientists, and women engineers in particular, more voice in the decision making process may be an innovative alternative for the diversity and flexibility needed for the unknown technological problems of the future. But first women scientists need to know how the system measures scientific achievement and how to identify the processes needed to increase our technological capability in order for them to formidably compete and win higher ranking positions.

Introduction

The United States is in the midst of an economic change that most would agree is comparable to the Industrial Revolution. It is the threat of losing our dominant position in the world market that has caused deep concern and action by legislators and businesses. Foreign competition and the decay and dislocation of our manufacturing industries has caused a nation to look toward high technology for new economic growth. When the economy was growing rapidly, it was a concomitant belief, albeit an unchallenged belief that research fueled this expansion. The country is undergoing major transformations in order to reclaim its hegemonous position in the world economy. While we are still at a formative stage in this process, serious issues need to be addressed. Some of the key questions to be asked are: Can science and technology research assure us a dominant position as a world leader? How much money should be spent on science and technology research, and what should it be spent on? Who are the true beneficiaries, and will this change only perpetuate women's subordinate place in society or provide new possibilities for them? It is the purpose of this paper to investigate the revolutionary changes being made in our society and their impact on women in

general, and women engineers in particular, as well as their work.

A nation's share in world trade in high-technology manufactured products is often used as a measure of its technological capacity (ref. 1). When considering the cause of our current economic crisis, the finger of blame points to our past technological performance. Since the 1980s, one of the most obvious and significant changes that has occurred is a trade imbalance between the number of manufactured products we exported and imported, particularly in the high-tech areas. Upon further examination, it becomes apparent that it was less of a deficiency in our own capabilities than it was a coordinated effort by our competitors at developing capabilities that manufacture goods of higher performance, a better quality, or a better price. When other nations, led by Japan, began to develop capabilities for synthetic innovation focusing on commercial products the U.S. started to lose its dominant position in the world market.

The U.S. economy has arrived at a point where other war ravaged foreign industries are now in a position to formidably compete with the U.S. for a larger portion of the world market. Between 1985 and 1987, the United States showed an increase in total national assets from \$30.6 trillion to \$36.2 trillion, while Japan's total national assets rose from \$19.6 trillion in 1985, to an unimaginable \$43.7 trillion in 1987 (ref. 2). The importance of this time frame is that it shows Japan, a small island with few natural resources, surpassing the U.S. in national wealth. This has resulted in shrunken profits and thus fewer resources to be allocated. The remedy became a short-term fix that borrowed heavily from foreign countries. By 1989, America's loss of economic power was reflected by a major decline in comparative world assets and purchasing power. This enormous transfer of wealth resulted in the U.S. being transformed from the world's largest creditor nation into the world's largest debtor nation. This economic decline has created doubts about not only the nation's ability to retain its influence and standing in the world, but its ability to retain its political and military power that ultimately depend on our economic strength and vitality.

What Can We Reasonably Expect from Science and Technology Research?

In 1983, Congress proposed over two hundred pieces of legislation to make science education and high technology a national priority. This consensus affirms the general belief that by strengthening our scientific and technological enterprises, we will revitalize our competitiveness in the global market which is now seen as crucial to both our country's well-being and military security. It is this understanding of technological innovation that suggests innovations are solely the product of research development. Although the evidence suggests otherwise, the U.S. has established a mechanism for systematically funding science while neglecting to establish a comparable system that promotes a technological process of innovation. The development of a science policy was assumed to carry within it an adequate technology policy.

It is difficult to demonstrate any clear correlation between research spending and the state of the economy. However, a frequently used indicator of a country's relative strength in science and technological capabilities is the number of Nobel Prizes awarded to its scientists. It is believed that the awarded Nobel Prize reflects the quality of an individual's contribution to science and if there are a number of Nobel Prizes awarded to individuals from a particular country, then that country would have greater potential or likelihood at being the world's leader in technological innovation and capability. Such a study was conducted to test the correlation between science achievement and industrial leadership. The national patterns of Nobel Prize winning were plotted against the rate of growth of either gross domestic product or manufacturing labor productivity. The results showed that among the countries that have hosted Nobel Prize winning science in chemistry and physics since 1945, the nations that have hosted fewer Prizes per capita have better economic performance, thus a negative correlation was identified (ref. 1).

The cash squeeze caused by our economic decline led to the development of "performance indicators" that not only assesses our national strength in science, but also its estimated relevance, effectiveness, productivity and investment return. What has become one of the most frequently-used indicators for estimating the quality of research is a statistical tool called bibliometrics. This approach uses the number of scientific publications and patents in a field that are authored by a nation's scientists as a measure of the quantity of that nation's contributions to that field. Some of the explicit assumptions of bibliometrics are that scientific research publications and U.S. patent records are legitimate measures of research output and that their citations and influence weights can be used to assess the relative importance of quality

research or its scientific impact. It would seem that high-quality scientific publications are cited more frequently by other scientists than other work. Bibliometric indicators are being used to charter a comparative analysis of international research productivity; investigate specific topics for key patents and their leading researchers in the field; monitor the research activity of key scientists; spot technological trends; and provide hard data for business firms for planning, acquisitions, partnerships, and overall strategic direction.

Research and development (R&D) programs reflect our government's role in determining the theoretically possible activities in selected areas, sectors, or product types. Creating an R&D institution for systemic innovation is quite new. It is now generally accepted that basic research is only one of the things a country needs in order to be successful in commercializing new technology.

If our national goal is to increase our ability to compete commercially in the world market, then we must develop our strategies more carefully. To be successful innovators, we must ask the question: How can we develop a better product in order to make it commercially more competitive? This information is not found in doing science, but by talking to our customers. Surveying customers' needs and listening to their desires is the first step. It should be noted that upon listening to the concerns and information being provided by the customer, it is the practical problems that have been the source for identifying fundamental questions and important innovations. If we ask how to make a product less expensive, of higher reliability, or a better match to our customer needs we are improving the quality of the design, production, or processing (ref. 3). By developing "total flexibility" within production systems, we are combining the custom-tailoring of products to the customers' needs and desires with the power, precision, and economy of modern production technology. The strategic goal will be to deliver high-quality products tailored to each customer at mass-production prices (ref. 4).

Stephen J. Kline, Professor of Mechanical Engineering at Stanford University, suggests that engineers need to be taught not only the basics of manufacturing and how to apply its principles, but also which forms of innovation are important in commercial competition." We need to teach some of our brightest engineers the basics of manufacturing and encourage them to continue career paths in this area. We also need to teach our engineers about which forms of innovation are more or less important in commercial competition, a topic we seldom address in our schools. There is a category of information called technological knowledge, which, although

considered inferior to scientific knowledge, on balance is more relevant for success in commercial markets.”

When examining the individual's role in innovation, we realize that this includes a broader use of the concept of technical knowledge. Technical knowledge includes not only what we call the principles of science but also an engineering analyses of problem solving not specifically addressed by science. This includes codes, practices, knowledge about controlling and trouble-shooting specific processes and systems, and many forms of specialized skills using trained coordinated muscle responses. For instance, operating machinery and instruments may require eye-hand coordination or similar time-response coordinated movements. This type of individual technical knowledge does not appear in published materials as much as in the coordinated reflexes of many working technologists. Problems that arise in the technological workplace exercise a major role in shaping the research agenda of science. The workplace can be used as a platform to observe the problems that arise in industry and may be our best source for innovative improvements. Workers' technical skills and experience are now an integral part of the innovative process. No longer is it to the advantage of management to treat their workers as a cost to be controlled but should be seen as an asset to be cultivated. The skills and experience developed by the worker are important sources for identifying significant innovative processes for greater productivity and future commercial products.

Women's Role in High Technology Innovation

The various skills and experiences the employee brings to the job may be an important source for identifying alternative solutions for the unknown technological problems of the future. The commercial market operates within an international market that by its very nature is diversified. When developing an innovative process that focuses on our competitiveness in the world market, diversifying our options, giving ourselves permission to view things differently, may be our greatest strength. Women as a group show this type of diversity in their skills, experiences, and perspectives. No single person can be expected to have the definitive answer for our future problems. However, listening to a variety of suggestions may provide the pieces needed to arrive at the best possible solution. The greater the diversity in employee participation, the greater the potential for more alternatives. Diversified alternatives will increase our options for the unknown problems of the future.

The more significant changes that have occurred over the past decade are the enormous increase in women's labor participation and the unprecedented rate at which change is occurring. The wage-earning American and working women in particular are experiencing the greatest impact of these changes. Over the past decade, almost 7 out of 10 new entrants to the American work force have been women. Between 1975 and 1985 alone, more than 13 million women entered the workforce. By 1986, 55% of all women over the age of 16 were working outside the home (ref. 5). When many of the manufacturing jobs were lost or relocated, American males lost their means to earning a subsistence wage for their families. This resulted in women leaving the home and moving into the labor force in order to make up the differences in lost wages.

Today, in an economy where there is a "revolution" in women's labor-force participation there has been very little change in the conventional role structure of family life. On the average men perform an estimated 15 hours of household work per week while women perform 34. As many as a 25% of American husbands do no housework other than some basic child care (ref. 5). American motherhood has been transformed in less than a generation as well. In 1960, 20 percent of mothers with children under 6 years old were in the labor force, that has expanded to 58%, with most of them working full-time (ref. 6). Women's life duties show her constantly tailoring her work and abilities to fit the needs and demands of those who are her responsibility. Restructuring job duties on demand, broadening responsibilities, taking on new tasks in regular job rotations both in and outside the home produce a female work force with the potential for responding more rapidly and creatively to new problems. Skill and flexibility are the result of work experiences in a variety of assignments.

According to the MIT Commission on Industrial Productivity, innovative bench-marking includes a team approach to product and process development, closer relations with suppliers and customers, and a more democratic workplace that includes flatter organizations, increased sharing of information, employee participation in decision-making, profit sharing, increased job security, a commitment to training, and continuous improvement. Innovative factors such as these can only work to the advantage of women who often get shut out of the scientific and technological enterprises. Like the timeline of any research program, there are only a few strategic points at which input into the decision-making process is feasible or effective. For instance, technological design is at its most flexible during the initial stages of the process. Other opportunities present themselves at the beginning of each phase or subphase of production. The further along in the process, the less of an impact later decisions

will have on the final product. Once in motion, the possibility of changing or halting its implementation is unlikely (ref. 7). The same timeline exists for any process; the window of opportunity occurs at the formative stage. It would seem more equitable and innovative to have women better represented in the decision-making process where change is most likely to occur whether on committees or throughout the production process. Women as a group show a unique diversity in their skills, experiences, and perspectives. If we consider our place in time and the diversity of our challenges in front of us, it is clearly the moment to more seriously consider a woman's point of view. A traditional, one-dimensional approach to innovation is self-defeating to the whole process. The greater the diversity in employee participation the greater the potential for more alternatives. A multi-dimensional approach to problem-solving increases our options for the unknown problems of the future.

Conclusions

The rapid rate of technological change is expected to continue. The U.S. is an integral part of the world market and our economy will continue to reflect our relative success at international commercial competition. The long term solution to our economic problems is continuous innovation which includes a better combination of market forces, consumer preferences, and technological opportunities. An era of "total flexibility" by production systems will combine the custom-tailoring of products to the customer needs and desires with the power, precision, and economy of modern production technology. The strategic goal will be to deliver high-quality products tailored to each customer at mass-production prices.

Regardless of how much a company invests in capital equipment, automation cannot replace human mastery of modern technology and experiences. Innovative human-resource policies promote participation, trust, flexibility, employment security, and teamwork. The enormous increase in women's labor force participation, an unfair share of domestic duties, a subsequent newly structured motherhood, and a lack of support by business and government show women as having an enormous capacity for flexibility and strength. Workers, managers, and engineers will be continually and broadly trained in the

continuous innovation needed for a diverse international market of which women are already showing an enormous capacity.

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Biography

The author has a B.A. in Biological Sciences and Chemistry and an M.A. in Sociology. Her past work experiences have been as a librarian in a major university research library and at the Library of Congress. Today, she is a librarian at the VMS Laboratory, NASA Ames Research Center.