

DR. SHIRLEY ANN JACKSON, a theoretical physicist, became the 18th President of Rensselaer Polytechnic Institute in July 1999. Her career prior to that position has encompassed senior positions in government, industry, research, and academia. In 1995 President Clinton appointed Dr. Jackson to serve as Chair of the U.S. Nuclear Regulatory Commission (NRC). As Chair (1995–1999), she was the principal executive officer of and the official spokesperson for the NRC.

While at the NRC, Dr. Jackson initiated a strategic assessment and rebaselining of the agency, leading to a new planning, budgeting, and performance management system, which established more business-like procedures for NRC activities. She also introduced risk-informed, performance-based regulation to the NRC, which is now being infused throughout its regulatory programs. She led the development of a new reactor oversight program, and created, with the Commission, a license renewal process resulting in the first license renewal (March 2000) of an operating reactor in the United States. Also while at the NRC, Dr. Jackson spearheaded the formation of the International Nuclear Regulators Association (INRA) in May 1997, and was elected as the group's first chair, a position she held from 1997 to 1999.

From 1991 to 1995, Dr. Jackson was Professor of Physics at Rutgers University. She concurrently served as a consultant in semiconductor theory to AT&T Bell Laboratories. From 1976 to 1991, Dr. Jackson conducted research in theoretical physics, solid-state and quantum physics, and optical physics at AT&T Bell Laboratories in Murray Hill, New Jersey. For her research she was named a Fellow of the American Academy of Arts and Sciences and of the American Physical Society. She is a member of a number of other professional organizations and holds 12 honorary doctoral degrees.

Dr. Jackson is the first African-American woman to receive a doctorate from the Massachusetts Institute of Technology—in any subject, one of the first two African-American women to receive a doctorate in physics in the United States, the first African-American to become a Commissioner of the NRC, both the first woman and the first African-American to serve as the Chair of the NRC, and now the first African-American woman to lead a national research university.



*Dr. Jackson spoke at the Millennial Challenges Colloquium series on 14 April 2000.
The text of "Science and Engineering Education of Women in the
21st Century" follows.*



Science and Engineering Education of Women in the 21st Century

Shirley Ann Jackson

I am honored to participate in this long-standing and popular colloquium series here at The Johns Hopkins University. Many of the subjects that have been discussed at these sessions—from the Internet and telecommunications, to imaging and “smart shoe” technology—are changing daily, thanks to continuous technological advances. This explosive growth of technology has revolutionized the global marketplace. Consequently, higher education must reevaluate its own role in this economy and the impact that it can and does have. As John Reinert, 1998 president of the Institute of Electrical and Electronics Engineers, said, “The degree to which America prospers . . . will depend on our collective ability to instill scientific knowledge and develop scientific skills in our youth; provide workers incentives and access to opportunities for lifelong learning; and raise the level of technological literacy among all our citizens.”

Clearly, the advances of tomorrow depend upon the solid education of today's students. We will need every last one of those students to be contributing members of the global society. I often have made the point that this country does not have people to waste because the challenges facing our nation are too great to ignore. And, we cannot afford to undervalue the capabilities of a significant portion of the population—women—if we hope to maintain our world leadership. Women in mathematics, the sciences, and engineering indeed have come a long way since the 1960s, when Donna Shirley was the only degreed female out of 2000 engineers employed at the Jet Propulsion Laboratory. Yet there is still much to be done.

WOMEN IN BUSINESS AND THE SCIENCES

Thanks to the trailblazers of the past few decades, women today have more role models in the professional ranks than ever before, including the first CEO at a Dow 30 company, Carly Fiorina of Hewlett-Packard. And women have led the successes of newer companies that have become household names: Meg Whitman has built eBay into an overnight success story, and Joy Covey is currently the chief strategist behind Amazon.com. Two of the three largest U.S. banks have female financial chiefs: Dina Dublon of Chase Manhattan and Heidi Miller at Citigroup. In medicine, half of all M.D. degrees go to women, and the American Medical Association has had its first female president, Dr. Nancy Dickey.

The Problem of Underrepresentation

Despite this increase in professional role models, minority and female representation in science and engineering is still embarrassingly low across the country. According to the most recent *Digest of Education Statistics*¹ compiled by the U.S. Department of Education, the number of women earning degrees in higher education has increased to more than half of those awarded. However, women are earning only 19.4% of all the engineering and physical science degrees awarded. This disproportion continues into the labor force where, according to a recent study by the American Association of University Women, only 6% of women are working in nontraditional careers. While two out of three minimum-wage earners are women, they are predominant in only 20 of the more than 400 existing job categories.

What is keeping women from pursuing the full spectrum of career opportunities available to them? This complex issue must be dissected and analyzed before it can be remedied. It will require a level of perseverance and creativity similar to that posed by the scientific and engineering problems we deal with in our careers. Nancy Ramsay, former legislative director to Senator John Kerry, once said,

If we can put women into business, law, and medicine at levels nearly equal to men, why can't we do it in engineering? If engineers can put people on the Moon and robots on Mars, surely they can figure out how to put women in engineering.

Steps have been taken. In 1998, the U.S. Congress mandated the formation of the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development to examine this issue. This group was expected to issue its findings to President Clinton and Congress in June 2000, thereby laying out a national road map for improving the levels of women and minorities in these fields.

Educational and Career Obstacles

But we already know some of the obstacles facing women in science and engineering. Recently, Catherine Didion, executive director of the Association of Women in Science, polled members about their major concerns, which mirror those identified in the many books and studies on the subject. First, respondents said that effective mentoring systems are needed to support women throughout their careers. Some researchers who study the issue of women in science have identified this as the most crucial need for women. Female mentors and role models of all ages and experience levels can help women steer clear of obstacles and roadblocks, make the contacts necessary to further their career objectives, and develop their own networks and support groups.

Second, those polled said that there must be more support of career flexibility. As Suzanne Franks of Kansas State University has written, professors tend to indoctrinate their students with the belief that the best career path and the only one worth pursuing is the one that they have chosen: the path leading to a tenured professorship. However, in today's new economy, there are also many nontraditional science careers in which scientists and engineers can apply their knowledge. In many cases, these alternatives may be more appealing to women because they enable them to meet the challenging demands of work and family.

The advent of new technology, particularly the Internet, can and will profoundly impact career flexibility. Its effect on women's careers and women's ability to achieve the highest levels of leadership in corporations, universities, and government cannot be overestimated. For those women who temporarily leave their careers with the hope of later reentering the workforce, the Internet provides a unique opportunity. Universities and corporations can allow women to remain engaged with their education and their work if they choose to stay home with their children, thereby reducing the impact the decision can have on their careers.

Finally, respondents to the Didion survey noted that there must be more accountability by institutions to keep and provide better statistics on the recruitment, retention, and promotion of women in science.

REMEDIES

Beyond those three major concerns, I have always felt that women need a sense of community in the sciences. In other words, we need our own equivalent of what is sometimes referred to as the "good old boys network." Of course I do not mean to suggest that we should practice exclusivity or favoritism. Rather, in an environment where women are in the minority, it is vital that we understand our own demographics and actively promote increased participation in the sciences.

Role Models and Speaking Out

At the 1999 National Academy of Engineering Summit on Women in Engineering, Donna Shirley, former manager of the Jet Propulsion Laboratory Mars Exploration Program, stated that more visible role models would also help attract more women into science careers. The popular media today show few female scientists and many stereotypical portrayals of mad scientists and nerds, she pointed out. Some scientists and authors have become household names such as Steven Hawking and Carl Sagan, and authors like Tom Clancy and Michael Crichton are popular for their high-tech novels. "But," she asked, "where

are the women engineers and scientists writing popular literature?"

Women in the sciences, technology, and engineering need to speak out about their experiences, their fields of expertise, and their contributions. Angela Pattatucci, in her book, *Women in Science*,² says, "Women must claim ownership of science rather than seeing ourselves as trespassers on the private property of men." She goes on to state that we must integrate ourselves into the structure of the academy by stepping up to serve on study sections, review panels, and editorial boards and by assuming leadership roles in societies and organizations. We must be not only visible, but vocal.

Improving Science Education

To achieve success, women must be armed with the skills necessary to thrive in this new economy. There are specific strategies that can be pursued to improve the education of women in science, engineering, math, and technology. However, to keep pace with and meet the needs of a world economy based on technology, we need to improve the science education of *all* students—both women and men.

In 1996, The National Science Foundation issued a report, *Shaping the Future: New Expectations for Undergraduate Education*.³ It examined the climate for undergraduate science education and made recommendations to ensure continuous improvements in undergraduate education in general. While small changes can and have made a difference, the report noted that

[U]ndergraduate education will not change in a permanent way through the efforts of Lone Rangers. Change requires ongoing interaction among communities of people and institutions that will reinforce and drive reform.

Although true change will require a partnership among industry, higher education, and K–12 education, the bulk of the responsibility rests directly in the lap of higher education. We are educating not only tomorrow's scientists, engineers, and technical workers, but also the students who will go back to the K–12 system and teach the next generation of our undergraduates.

Faculty at colleges and universities can help break the vicious cycle of inadequate education by improving science literacy. We must develop programs to expose K–12 teachers to the latest innovations and current research. The fields of math and science are changing so rapidly that we cannot expect teachers educated just 5 or 10 years ago to keep up with current innovations and cutting-edge technologies. The challenge is to continually engage teachers during the summers as professional associates in university and corporate innovation and research, and to use information technology and the Internet to engage them as partners during the academic year.

The enthusiasm and excitement that teachers develop through their own experiences will translate into a more vibrant and exciting class for students. Excitement is contagious, and I have no doubt it will influence some students who may never have considered a career in science, math, or engineering to explore these fields.

And, we cannot afford to undervalue the capabilities of a significant portion of the population—women—if we hope to maintain our world leadership.

That same excitement and innovative teaching are also critical to the undergraduate classroom. A study of undergraduates in the natural sciences and engineering in the early 1990s was very critical of faculty teaching practices. Nine out of 10 science majors who switched to a nonscience or nonengineering major and 3 out of 4 who persevered described the teaching they received as poor. Students strongly believed that faculty do not like to teach; that they do not value teaching as a professional activity; that they lack incentive to improve; and that obsession with research is the main reason they do not pay serious attention to teaching undergraduates. Interestingly enough, the study noted that student condemnation of the faculty obsession with research changed dramatically when students were allowed to observe or participate in that research.

Faculty members can take advantage of this phenomenon and more effectively engage students. Think back to the beginning of your own interest in science. It is likely that a taste of hands-on experimentation in the laboratory piqued your interest. Or perhaps an enthusiastic teacher's demonstration sparked your passion for science or engineering.

Creatively involving students in hands-on science, and engaging, mentoring, and teaching these new generations of students who were raised on technology will require innovative and enthusiastic teaching. Faculty at all levels must learn to apply the new technologies available to make instruction more effective. For example, at Rensselaer we have developed a new paradigm for undergraduate education, which not only creates a more engaging experience, but also fosters teamwork and leadership.

In Rensselaer's signature studio courses, students are freed from long lectures in favor of a more collaborative style that employs a variety of media and group projects. Students must work together to successfully complete their education at Rensselaer. And we are convinced that this kind of education will make them better

employees and colleagues in the new workplace. These lifelong learning skills will be critical in the coming century because those workers who can successfully navigate turbulent change will be most fruitful.

Colleges and universities also must develop mechanisms to provide faculty with adequate opportunity for training in new technologies so that they can bring them into the classroom. Students are accustomed to using new media and will expect it from their teachers. As new information about teaching methods becomes available, science faculty must examine these methods and use them.

In addition to innovative teaching, academia must have high expectations for all students. The National Science Foundation report³ notes that this has to be combined with a welcoming and encouraging climate for learning. We cannot teach with the mentality that “the best will survive and rise to the top,” which can be an excuse for preserving the status quo. Squandering the talent of students will not help us succeed. Universities must have an equal commitment to the academic success of *all* students. As Donna Shirley said,

If engineering education focused not only on developing the minds of the smartest individuals, but also on developing people who can be very effective working in teams, that would be a very good environment for attracting women.

Strategies in the Academic Community

We must also take a critical look at ourselves in academe. The Association of American Medical Colleges recently recommended to its own members ways for developing more women as leaders and facilitating change. Although targeted to medicine, the strategies are applicable to any discipline:

- Appoint women to search committees and insist that a woman appear on the “short list.”
- Add diversity to important committees. The products of diverse teams skilled at examining their methods and addressing disagreements are likely to be of much greater value than the products of teams that do not reflect their constituencies.
- Make the extra effort usually necessary to identify women candidates for top positions.
- Encourage committees to be trained in conflict management and to engage in discussions of leadership styles, including examination of gender stereotypes.
- When recruiting department heads, emphasize management and nurturance of faculty and development of team-building skills. Chairpersons should also be held accountable for meeting goals such as improving career guidance given to junior faculty and increasing the proportion of women faculty promoted.
- Regularly conduct self-assessments, focusing on whether the department is achieving its stated

mission, and evaluate student and staff perceptions of the learning and organizational climate.

These strategies can work. An example from my own experience is my work as Chair of the U.S. Nuclear Regulatory Commission, where approximately 30% of the professional staff are women. I established a staff leadership team composed of women, African-Americans, Asians, and white males. This group was one of the best leadership teams the NRC has ever had. They brought extraordinary talent, energy, sensitivity, and unique insight to their tasks, which were critical in helping the Commission fulfill its mission.

THE SPIRIT OF ADVENTURE

Increasing the number of women educated in science and technology will not happen overnight, nor will there be a magic bullet to fix the situation. But higher education must be a leader, be flexible, and use all the tools at its disposal, from the latest Internet technology to good old-fashioned, one-on-one mentoring. Only in this way will we give students the opportunity to explore the entire universe around them, not just the universe of their field of study. We must spark and nurture creativity and curiosity in our students.

I am reminded of something that Marie Curie said in 1933:

I am among those who think that science has great beauty A scientist in his laboratory is not a technician: He is also a child placed before natural phenomena which impress him like a fairy tale. We should not allow it to be believed that all scientific progress can be reduced to mechanisms, machines, gearings, even though machinery also has its own beauty.

Neither do I believe that the spirit of adventure runs any risk of disappearing in our world. If I see anything vital around me, it is precisely that spirit of adventure which seems indestructible and is akin to curiosity.

Precisely this spirit of adventure will be key in leveraging the technological changes of the next century. Encouraging that spirit and providing an atmosphere in which it can grow and develop are critical. Our country's future well-being depends on it.

REFERENCES

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