



Blueprint for the Future: Framing the Issues of Women in Science in a Global Context: Summary of a Workshop

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Catherin Didion, Lisa M. Frehill, and Willie Pearson, Jr., Rapporteurs;
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BLUEPRINT FOR THE FUTURE

Framing the Issues of Women in Science in a Global Context

Summary of a Workshop

Catherine Didion, Lisa M. Frehill, and Willie Pearson, Jr., *Rapporteurs*

**Committee on Status and Participation of Women
in STEM Disciplines and Careers**

Committee on Women in Science, Engineering, and Medicine

Policy and Global Affairs

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¹ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

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PREFACE AND ACKNOWLEDGMENTS

The scientific work of women is often viewed through a national or regional lens, but given the growing worldwide connectivity of most, if not all, scientific disciplines, there needs to be recognition of how different social, political, and economic mechanisms impact women's participation in the global scientific enterprise. Although these complex sociocultural factors often operate in different ways in various countries and regions, studies within and across nations consistently show inverse correlations between levels in the scientific and technical career hierarchy and the number of women in science: the higher the positions, the fewer the number of women.

Understanding these complex patterns requires interdisciplinary and international approaches. In April 2011, an ad hoc committee overseen by the National Academies' standing Committee on Women in Science, Engineering, and Medicine (CWSEM) convened a workshop entitled, "**Blueprint for the Future: Framing the Issues of Women in Science in a Global Context**" in Washington, D.C. The purpose of the workshop was to identify strategies, core data, and important guidelines for implementing policies and procedures that will increase women's participation and advancement in the global science enterprise. The presentations and discussions at the workshop highlighted some of the research results and findings on women in selected science fields and helped to identify critical gaps in data and the research.

The scope of the workshop was limited to women's participation in three scientific disciplines: chemistry, computer science, mathematics and statistics. Although three fields cannot represent the distinct and diverse nature of all science, the choice of three permitted the workshop participants to focus in greater depth on common areas. These fields were chosen because they have significantly different levels of female participation in degree programs in several countries, and some of these differences continue into the workforce (see Appendix D, Table D-2). In addition, chemistry and mathematics have a long history of international organizations that have facilitated international collaboration and research in their respective disciplines.

This project began in 2008 under the auspices of the American Institute for Research and continued at the Commission of Professionals in Science and Technology until it was transferred to the National Academies in 2010. The workshop should serve as a useful foundation for future work on women in international science which looks at science in a more disaggregated fashion, taking into account critical differences in the ways that organizations are structured, routine practices in the training of scientific workers, and interactions within work organizations and among researchers located in different nations—all of which vary across disciplines.

The workshop represented a rare opportunity to examine the status of gender in science across many countries. At the same time, workshop participants were cognizant of the difficulties of establishing clear cross-national comparisons given the lack of pertinent or comparable data. The workshop was an opportunity to identify common issues in the advancement of women in chemistry, computer science, mathematics and statistics, and we hope this summary will serve as a catalyst for future efforts at global and regional levels, providing scientists and policymakers with a framework for exploring the global context of women's participation in their individual scientific disciplines. The data and information from the workshop presentations that are referenced in this report are available on the CWSEM website: www.nas.edu/cwsem.

This summary has been prepared by the rapporteurs as a factual summary of what occurred at the workshop. The ad hoc committee's role was limited to planning and convening the workshop. The views contained in the summary are those of individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Academies. Rita S. Guenther contributed to the completion and production of this workshop summary.

The workshop agenda is provided in Appendix A, with the biographies of the speakers and a list of workshop participants in Appendixes B and C. Appendix D contains data on women researchers in science provided at the workshop. Finally, speakers were invited to submit papers to provide further detail about their presentations, and their papers are found in Appendix E.

This report has been reviewed in draft form by persons chosen for their diverse perspectives and scientific expertise in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of the report: Judy Franz, The American Physical Society; Sharon Hrynkow, U.S. Department of State; Susan Staffin Metz, Stevens Institute of Technology; Lynette Osborne, George Washington University; and Patricia Taboada-Serrano, Rochester Institute of Technology. Although the reviewers listed have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. Responsibility for the final content of this report rests entirely with the authors and the institution. This material is based upon work supported by the National Science Foundation under Grant No. 1048010. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Catherine Didion

Lisa M. Frehill

Willie Pearson, Jr., Rapporteurs

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1

WELCOME AND OVERVIEW OF WORKSHOP**1.1 Welcome and Overview**

Allan Fisher, vice president of Laureate Education, Inc., **Carol Stoel**, program officer in the National Science Foundation's (NSF) Division of Graduate Education, and **Catherine Didion**, director of the Committee on Women in Science, Engineering, and Medicine (CWSEM), welcomed the attendees of the workshop. They thanked both the group of scholars and professionals who have dedicated their time to understanding this topic, and Fisher and Didion thanked NSF for funding this project over the years. Fisher described CWSEM's mandate, which is to coordinate, monitor, and advocate action to increase the participation of women in science, engineering, and medicine.

In his remarks, Fisher explained that the workshop presentations came from a group of scholars and professionals who have been working for several years on documenting, analyzing and interpreting the status of women in selected technical fields around the world. Examination of the three disciplines—chemistry, computer science, and mathematics and statistics—can be considered a first foray into collecting and analyzing information that can be replicated in other fields. The complexity of studying science internationally cannot be underestimated, and the presentations to follow demonstrate some of the evidentiary and epistemological challenges that scholars and professionals face in collecting and analyzing data from many different countries and regions.

A long-time participant in studying the representation of women in science, Stoel thanked earlier researchers for their work in this area. In the late 1960s and 1970s, there were only nine women college presidents in the United States, and they were all at Catholic women's colleges. The number has increased greatly over the years. Stoel emphasized that "things come and go, and we need to figure out what is underneath the patterns so that we can preserve what has been accomplished and move forward." The topics discussed in the workshop need to be acknowledged as important and need to be incorporated with appropriate international experiences.

Didion and **Lisa M. Frehill**, senior program officer at the National Academies, explained that this workshop builds on a project initiated several years ago by Willie Pearson, Jr., Cheryl B. Leggon, Daryl Chubin, and Shirley Malcom, which has expanded to include international colleagues. Throughout the planning of the workshop, Frehill commented, the planning committee provided opportunities for those working on the project to meet, discuss cross-cutting themes, make comparisons, and consider a large number of diverse source materials from many disciplinary traditions. Since 2009, the team of Lisa Borello and Sybrina Atwaters, led by Pearson at Georgia Institute of Technology, has compiled these sources and established an annotated bibliography, which continues to grow as the work progresses.

Frehill further noted that the workshop has brought together social scientists who study the social structures of gender, science, and technology; advocates of women's participation in the disciplines under consideration who trained practitioners in those specific disciplines; and those who are involved in programs and policy work related to women's participation in the sciences. The presented data provided a snapshot of the current status of women in the selected disciplines, as well as illustrate the methodologies by which data need to be examined to permit cross-national comparisons of women's participation in science.

The workshop presentations provided an opportunity for dialogue about the issues that the authors have been pursuing in their work to date. Limited to 10 minutes, the presentations highlighted only some of the information contained in the presenters' papers included in the summary (see Appendix E).

Panel I—Cross-Cultural Issues

Panel I consisted of four presentations that addressed the foundational and cross-cutting themes within the larger global framework for the role of women in science. **Angelica Salvi Del Pero**, administrator of the Gender/Social Policy Division under the Directorate for Employment, Labor and Social Affairs at the Organization for Economic Cooperation and Development (OECD), presented international comparative data on women in science from both OECD member and nonmember countries. **Mariko Ogawa**, professor of history of science and science studies at Mie University in Japan, provided a global historical perspective on women's participation in the chemical sciences, computer science, and mathematics and statistics.

She was followed by **Anne MacLachlan**, senior researcher at the Center for Studies in Higher Education at the University of California, Berkley, who presented her perspective on the cultural parameters affecting female participation in educational systems in the highlighted fields. Finally, **Alice Abreu**, the regional coordinator of the International Council for Science Rio+20 Initiative and professor emeritus of the Federal University of Rio de Janeiro in Brazil, provided an overview of the metrics and methods used in occupational sex segregation research to understand sex differences in the distribution of women and men in different positions in academia and the workforce.

2.1 Knowledge and Data Sources¹

Angelica Salvi Del Pero

Organization for Economic Cooperation and Development (OECD)

Salvi Del Pero presented preliminary findings from a new OECD gender initiative, which examines gender equality in three areas: education, employment, and entrepreneurship (3Es). The data presented provided statistical comparisons for both OECD and non-OECD economies in an attempt to identify gaps, patterns, and links among the 3Es; particular emphasis was placed on emerging economies.

Using data collected for the Program for International Student Assessment (PISA), gaps between high-school boys' and girls' average scores on competency tests in reading, math, and science were determined. In terms of reading scores, Salvi Del Pero emphasized that on average, girls performed significantly better than boys across all countries. The largest overall gender gaps were observed in Finland, the Slovak Republic, and Slovenia, and, where gaps were as high as 10 points in favor of girls. The three smallest overall gender gaps were observed for Brazil, The Netherlands, and the United States, where gaps approached 5 points. Conversely, the boys'

¹ See Appendix E-1 for the full paper.

average score in mathematics surpassed those of girls' by a gap of five points or less. Only two countries, Indonesia and Sweden, exhibited results where girls outperformed the boys in mathematics. Performance sex gaps in science were generally negligible and inconsistent, having gaps of less than 2 points and no overall gender advantage.

The sex gaps widen for degrees earned in tertiary education. A review of first tertiary degrees awarded in mathematics and computer science or engineering, manufacturing, and construction² shows large sex gaps that do not correlate with PISA performance in mathematics and sciences. Males earned a greater portion of degrees awarded in mathematics and science. Salvi Del Pero stated that even the relatively small sex gap in mathematics performance does not adequately explain the lower participation of females in mathematics as a degree or career choice. Instead, motivation measures showed a greater correlation with sex gaps in degree attainment. Motivation was measured using an index that included student assessments of how interesting the subject was and how relevant the subject would be for their career choice. Preliminary findings suggested that girls were less motivated to select mathematics and engineering majors.

On the basis of this evidence, Salvi Del Pero recommended three policy initiatives that engage girls earlier in mathematics and computer science to encourage greater participation in these fields. First, she recommended working toward a better gender balance of teaching staff in kindergarten and in basic education. Second, professional role models are a key to gender equality in all three areas, so “masculine” professions should intentionally be promoted among young women and “feminine” professions among young men. Third, preliminary findings suggested that stereotyping is still paramount in addressing motivation measures in science, mathematics, computer science, and engineering-related fields. Salvi Del Pero proposed that stereotyping be addressed in educational and training choices at school (and at home); policies to address stereotyping in education should not be conceived as isolated initiatives. A gender-difference initiative should be complemented by more general efforts to combat gender stereotyping in social messages and should not clash with the messages conveyed via the media and the observations of the actual patterns of employment.

Finally, Salvi Del Pero presented data based on a survey of college graduates employed at their first job at least 5 years after tertiary graduation, as shown in Table 2-1. The data suggested that different pathways in employment emerged for women and men. Over 55 percent of males who majored in science acquired jobs in physics, mathematics, or engineering after graduation. In contrast, only 34 percent of female majors in these same areas obtained positions in related fields. Correlation of these results to other fields was

Over 55 percent of males who majored in science acquired jobs in physics, mathematics, and engineering after graduation. In contrast, only 34 percent of female majors in these same areas obtained positions in related fields.

--Angelica Salvi Del Pero

not possible. For example, 68 percent of females who majored in humanities secured teaching positions after graduation; only 52 percent of similarly trained males secured similar positions. Further analysis is necessary to explain these different outcomes for men and women, including understanding “What are the influences of expected outcomes on the labor market.” In the near-term, Salvi Del Pero and her associates will address this question using additional surveys of college graduates and longitudinal PISA data. Additionally, every three years since 2000, OECD

² The OECD aggregates “mathematics and computer science” and “engineering, manufacturing, and construction.” In some cases, these fields are disaggregated.

has followed up with PISA respondents. Survey respondents who recently attended college are now entering the labor market, and the project team will seek to identify emerging causal patterns along the pathway to scientific careers.

TABLE 2-1. Occupation and Field of Study Correlation Table for PISA-Tested Students by Gender for Six Countries (in percentages)³

Occupation	Physics, Mathematics, and Engineering	Life Sciences and Health	Teaching	Other	Total
Field of study, males					
Humanities	7.94	0.89	52.36	38.80	100.00
Social sciences	13.40	1.14	7.71	77.75	100.00
Science	55.32	18.40	13.80	12.49	100.00
Health	8.35	76.56	3.12	11.97	100.00
Total	23.03	15.44	16.79	44.74	100.00
Field of study, females					
Humanities	1.98	1.70	68.43	27.89	100.00
Social Sciences	5.45	2.43	11.42	80.70	100.00
Science	33.65	28.91	22.12	15.32	100.00
Health	5.61	69.89	5.15	19.35	100.00
Total	7.54	21.06	29.92	41.48	100.00

SOURCE: “OECD Gender Initiative: Strengthening Gender Equality in Economic Opportunities.” Presentation made by Angelica Salvi Del Pero at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

2.2 Socio-Historical Trends⁴

Mariko Ogawa
Mie University in Japan

Ogawa presented a historical sketch of women’s participation in chemistry, computer science, and mathematics before 1960, developed with collaborators Lisa M. Frehill and Sophia Huyer. Ogawa’s presentation covered noteworthy graduate degree recipients, women’s engagement in professional societies or guilds, female Noble laureates, and women’s impact on significant research findings for each of the fields of interest. The team’s findings refute arguments that historically suggested women were not capable of, or lacked interest in, scientific fields.

³ The six countries are Australia, Canada, Denmark, Slovakia, Switzerland, and Uruguay.

⁴ See Appendix E-2 for the full paper.

Although the number of female students in chemistry has been increasing in recent years, historically female chemists were relatively scarce. One explanation focuses on the importance of laboratory work in the chemical sciences, which necessitates access to resources and poses demands on maintaining a balance in private life. There were some notable exceptions, such as Marie Curie who earned two Noble Prizes. Her first Noble Prize was awarded jointly with her husband in physics in 1903, and the second was in chemistry in 1911 to her alone.

Other exemplary women in the chemical sciences worked with William Black and his son in the area of crystallography in England. Kathleen Lonsdale, Dorothy Hodgkin, and Rosalind Franklin were among them. Each of these chemists greatly contributed to the field: Kathleen Lonsdale was elected as the first female member of the Royal Society in 1945; Dorothy Hodgkin was award the Nobel Prize in chemistry in 1964; and Rosalind Franklin became known for her crucial contribution to the identification of the double-helical structure of DNA. Ogawa suggested that these exceptional cases demonstrated that environment and encouragement were important to women's participation in the chemical sciences.

Similar to chemistry, Ogawa offered analogous historical misconceptions of women in mathematics. Utilizing the images of the two dolls (Figure 2-1)—Barbie, from the United States, and Licca, from Japan—Ogawa highlighted the cultural issues associated with girls' formations of career possibilities by asking, “What is a common characteristic of popular dolls?”



FIGURE 2-1. “Math Myth”— A Common Characteristic of Popular Dolls

NOTE: Figure created by Mariko Ogawa for the presentation “Historical Sketch of Women in STEM Disciplines and Careers with a Focus on Three Disciplines: Chemistry, Mathematics, and Computer Science” delivered at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

SOURCE: iStock (Barbie doll) and Takara Tomy (Licca doll). Reprinted with permission of Takara Tomy.

The suggestion is that both Barbie and Licca are poor at math and primarily interested in the arts. These dolls represent popular conveyors of the “math myth” that girls are not good at, or interested in, mathematics.

Ogawa argued that in spite of the modern “math myth” there are many women who enjoy mathematics. Women’s participation in mathematics is not as problematic as some other science and engineering fields. This finding may be the result of work and research in mathematics usually not being tied to a laboratory or similar types of locations and is often conducted alone. Ogawa reviewed the 18th and 19th century series of *Ladies Diaries*⁵ as an example of women’s popular engagement in solving complex mathematical problems and offered Charlotte Scott, Grace Young, and Julia Robinson as additional famous female mathematicians. She stated that in Russia and Germany, there were excellent female mathematicians. The first woman to earn a Ph.D. in mathematics was Sofia Vasilyevna Kovalskaia, a Russian mathematician who earned her doctorate in absentia from the University of Göttingen.

Relative to chemistry and mathematics, women’s participation in computer science is emergent because of the relative newness of the field for both sexes. However, a few notable female computer scientists do exist. Ogawa highlighted the accomplishments of four famous computer scientists: Countess Lovelace (1815-1852), first developer of conceptual programming for Charles Babbage’s Analytical Engine; Mary Keller, founder of the computer science department at Clarke College in Dubuque, Iowa; Thelma Estrin, president of the Institute of Electrical and Electronics Engineers’ Engineering in Medicine and Biology Society in 1977; and Rear Admiral Grace Hopper, who developed the COBOL programming language.

In conclusion, Ogawa presented a historical perspective of some of the challenges and issues associated with assessing women’s participation within a global context. Much of the literature on the pre-1960 era came from Western Europe and North America; future research needs to find ways to engage multilingual literature for broader global coverage. Similarly, modern science is relatively new in many countries, and it is difficult to locate information regarding the status of women in science in a global context. Ogawa proposed that the colonial past and the national paths to independence have significant implications for women’s participation in science. Last, the chemical industry is capital-intensive and mobile. As a result, new labor forces are developed as capital moves across international boundaries. Ogawa emphasized that future research needs to consider the interaction of gender in each of these new contexts to effectively understand the role of women in chemistry, mathematics, and computer science worldwide.

2.3 Higher Education⁶

Anne MacLachlan

University of California, Berkeley

MacLachlan provided a historical perspective on the development of the research university and its impact on women’s participation in the scientific fields under discussion. The research university (defined as a doctoral conferring institution) has a monopoly on awarding doctorates as well as on the facilities necessary for training students in scientific fields. According to MacLachlan, “the research university has become the embodiment of western science.” She attributed the dominance of the research university to a number of factors, including the requirement of surplus wealth to develop higher education institutions globally, the

⁵ The *Ladies Diaries* contained complex mathematical problems and was a part of a contest in Europe. It was designed specifically for the amusement and entertainment of women with an appendix of curious and valuable mathematical papers for the use of students.

⁶ See Appendix E-3 for the full paper.

necessity for a good primary and secondary education to feed these universities, and the adherence of national and international norms that govern teaching and practice of science and mathematics. Professional or disciplinary societies also influence the structure and content of higher education, because they maintain and develop the norms that govern a particular field.

MacLachlan suggested that the traditional elitism of professional societies and research universities is a possible barrier to women's participation in chemistry, mathematics and statistics, and computer science. The origins of the research university can be traced to institutions created by the Catholic Church to train men for the priesthood, medicine, and law. These institutions existed separate from the larger society, and attendees were privileged above most sectors of society, excluding the monarchy. The implications of being an elite group still apply to the practice of science in the 21st century.

Citing Tony Becker and Paul R. Trowler's *Academic Tribes and Territories*,⁷ she emphasized that teachers not only transmit knowledge, but also transmit a set of values associated with the culture of the research university. Becker's work suggests that each discipline has its own language, rites, and rituals. As was the case with the original universities of the Middle Ages discussed earlier, "interaction with others" is not valued; separatism is the greater aim. Thus, women's participation is not merely regulated by acceptance in an academic institution, but also by acceptance into an elite culture of academia.

Although the contributions of women historically in scientific fields may have been documented, MacLachlan noted that the conferral of doctoral degrees to women is predominately a 21st century phenomenon. Women received science Ph.D.s in the 1920s, but their participation in science at the doctoral level was more circumscribed and did not begin to change until the 1970s. "The presence of a woman brings a whole new value set and a set of expectations to disciplines which never had to think about social interaction much at all," she said. And new values and expectations often clash with the historical values and expectations associated with each discipline.

With this backdrop, MacLachlan outlined a series of parameters to use in examining the participation of women in higher education that would take into account the historical development of universities, professional societies, and disciplines in individual countries. Such parameters include: the number and type of higher education institutions; the percentage of women attending tertiary education by age cohort; the year(s) that women were admitted to degree programs and the establishment of chemistry, mathematics and statistics, and computer science as university subjects; the founding of relevant professional associations; the current numbers of women earning postsecondary degrees in these fields; trends in degree conferrals over last 30 years; and the professional employment of women in these fields. Using these parameters, detailed analysis of women's participation in chemistry, mathematics and statistics, and computer science can lead to new insights and comparisons across countries and regions.

⁷ Becker, T. and P.R. Trowler. 1989. *Academic Tribes and Territories: Intellectual Inquiry and the Culture of Disciplines*. Philadelphia: The Society of Research into Higher Education and Open University Press.

2.4 Workforce Segregation⁸

Alice Abreu

International Council for Science Rio+20 Initiative

Abreu presented an overview of occupational sex segregation in computer science, chemistry, and mathematics and statistics from analysis conducted at three levels. The first (or macro) level describes differences in the labor market trends in the entire *society*. The second (or middle) level, examines how *institutional* processes of qualification, training, recruitment, and retention within scientific careers are affected by gender. The third and final level, the micro level of analysis, discusses the extent to which differences in occupational structures and careers reflect choices made by *individuals* and to what extent these choices are constrained by gender.

Addressing the macro level first, Abreu noted that intentionality is a key issue at this stage. A large spectrum of analysis was reported that ranged from cases in which work segregation by sex was explicit and others in which sex segregation was less intentional and largely an unintended consequence of choices and social processes. To understand the effects of intention on sex segregation among various sectors, Abreu referred to contributions by her coauthor, Frehill. These contributions used analytical tools to examine both horizontal and vertical workforce sex segregation. Horizontal segregation was highlighted by looking at segregation of doctoral recipients by thesis and sex in U.S. mathematics departments as shown in Figure 2-2, which illustrates how segregation occurs across different fields of study. In contrast, the segregation within a system, or vertical segregation, was shown by examining the distribution of male and female mathematics faculty across ranks, as shown in Figure 2-3. Abreu emphasized that of all U.S. doctoral-degreed mathematics faculty, only 20 percent of all female faculty hold full-professorship positions compared with approximately 50 percent of all male faculty.

Transitioning to the middle level of analysis, Abreu then discussed the processes that underlie the macro-level outcomes. At this level, she noted that elucidating these processes is important to understanding cross-cultural trending. For example, in some fields, women make up the majority of undergraduate students and, in some cases, the majority of doctorate students, but advancement of these women is not observed. Therefore, the process of recruitment and retention exists within realms that have been patterned by gender, but women consistently disappear at higher levels. Metaphorically, as Abreu commented, this pattern has been called the “leaky pipeline,” “the crystal labyrinth,” and “the glass ceiling.”

⁸ See Appendix E-4 for the full paper.

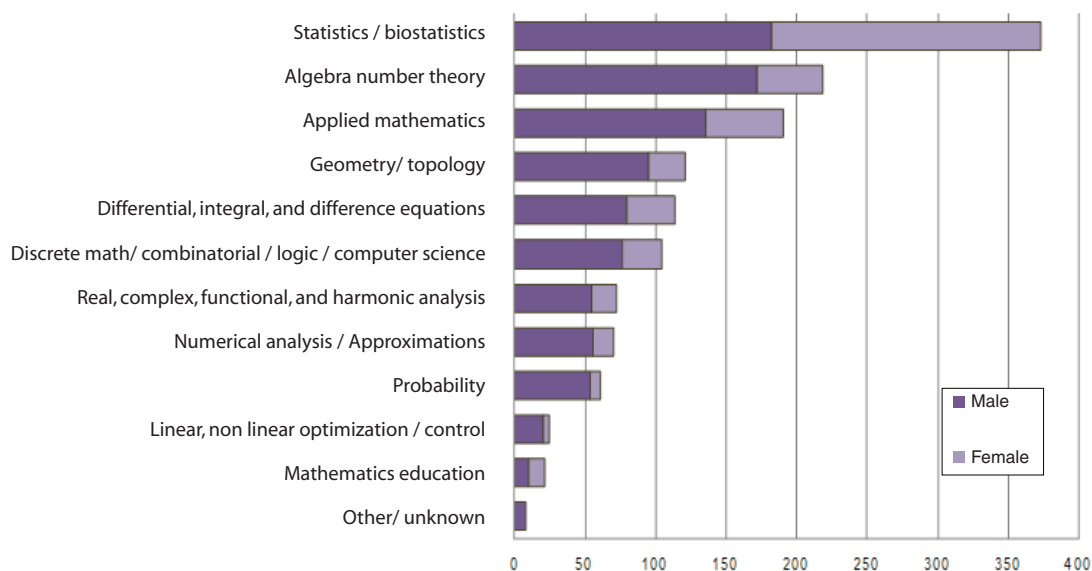


FIGURE 2-2. Horizontal Segregation: 2007-2008 Doctoral Recipients by Field of Thesis and Sex, U.S. Mathematics Departments

SOURCE: Analysis of data in Phipps, P.J.W. Maxwell, and C.A. Rose, 2009. 2008 Annual Survey of the Mathematical Sciences in the United States. *Notices Am. Math. Soc.* 56 (7):828-843.

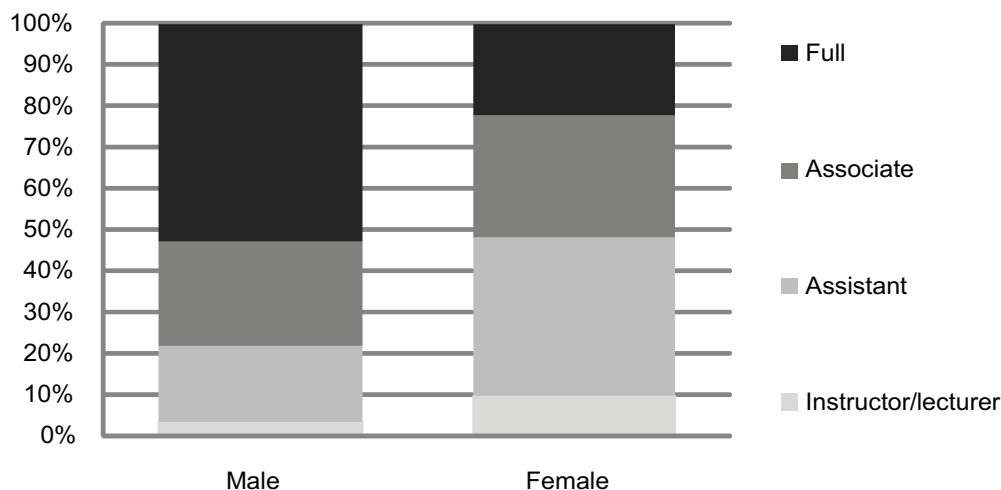


FIGURE 2-3. Vertical Segregation: U.S. Doctoral-degreed Mathematics Faculty by Sex and Rank, 2006

SOURCE: National Science Foundation (NSF). 2009. "Characteristics of Doctoral Scientists and Engineers in the United States, 2006." Detailed Statistical Tables NSF09-317.

Turning to emerging nations, Abreu used Brazil as an example of the presence of barriers to women's advancement in science and math that exist cross-nationally. Specifically, she explored several important stages in a scientific career: qualification and training; length of training from undergraduate to postdoctorate; recruitment; how to re-attract girls to science and math and retain them; and how to retain and advance women in these careers, for example, by entry to full professorship. Abreu stated that women represent over 25 percent of engineering Ph.D.s and 60 percent of biological sciences Ph.D.s in Brazil.

In Turkey, women account for more than 28 percent of engineering faculty but account for only 9 percent in the United States.

-Alice Abreu

It is interesting that these statistics show relatively high participation of women in science and math in Brazil compared with affluent countries. Yet, most emerging and affluent nations only employ a small percentage of full female professors in these fields. In Turkey, women account for more than 28 percent of engineering faculty but account for only 9 percent in the United States, a finding that makes one question whether these percentages reflect individual choices or social constraints that affect individual choices. Abreu emphasized that more work is needed in this area but is optimistic that the identification of these barriers can be understood and measured.

Finally, Abreu highlighted the need for micro-level analysis, where theories of individual choice must be re-examined. The debate is tumultuous—specifically regarding why women's representation in some STEM⁹ fields is so low, and why individual choices regarding academic fields of study and careers continue to be made along gender lines. For example, if sex segregation in the workforce can be explained by the individual choices of women in relation to gender preference, then why is gender difference more pronounced in the United States and affluent countries than in transitional and developing countries? Abreu suggested turning to women's social status (such as married versus unmarried) as one factor to consider at the micro level in understanding the occupational outcomes at the macro level.

2.5 Panel Discussion

Anneke Sengers, scientist emeritus from National Institute of Standards and Technology and chair of the Women for Science Working Group from the InterAmerican Network of Academies of Science (IANAS), began by referencing her most recent experience working with the IANAS in the western hemisphere.¹⁰ The 5-year old regional network includes 17 national science academies representing territories across North, Central, and South America. One of the important issues that IANAS wishes to address is the low-level position of women in the STEM workforce, especially in developing countries. Sengers noted that even at the national level, each national academy has had difficulty enhancing women's participation but still share the concern for women in science globally; each national academy is aware they have a problem and is receptive to change. IANAS has established a group to address the participation of women in science in 2010, and this working group has already generated results.

⁹ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

¹⁰ For more information, please see: <http://www.ianas.org/index.php/programs/women-for-science>. Accessed August 21, 2012.

2.6 Question and Answer Comments

Discussion Following Salvi Del Pero Remarks

Joanne Cohoon, associate professor in the School of Engineering and Applied Sciences at the University of Virginia, asked Salvi Del Pero whether the OECD report will include policy recommendations and proposed initiatives to address stereotyping that go beyond the examples provided in the presentation.

Salvi Del Pero responded, “Yes, it will definitely be a part of the report.” She went on to clarify that additional recommendations will not be in the interim report because the research team is in the process of completing a comprehensive review of global policies that have already been put in place. It is difficult to evaluate the impact of these current policies. As a result, the aim is to include recommendations and initiatives that will work and meet the objectives specified in the presentation.

Catherine Didion commented that she found the huge differences in representation of women in mathematics and computer science in the OECD data to be very interesting. She observed that there was no geographic pattern associated with the differences Salvi Del Pero detailed. Didion asked Salvi Del Pero whether she thought the framework of introducing boys to more feminine careers and girls to more masculine careers will work in a global context, considering the many cultural variances regarding which jobs and expectations are commonly associated with each gender.

Salvi Del Pero replied that they not only need to look at the field of employment but also more detailed occupational statistics. So far they have discovered that within certain fields of employment there is micro-segregation at the subfield level. She acknowledged that more complex analysis is needed, and OECD will have to think through how to map solutions into an international context. OECD is expecting to make the full report available by the end of fiscal year 2012.

Robert Lichter, a principal at Merrimack Consultants, LLC, inquired how OECD will go about gaining information regarding program outcomes. Salvi Del Pero indicated that the approach will be to ask collaborating or OECD member countries to provide information regarding program outcomes.

Cohoon followed up and asked whether OECD will look at trends over time in different countries. Salvi Del Pero replied in the affirmative. However, she explained that this task will be difficult using PISA data because the data have been collected only since 2000. Therefore, post graduation survey data may be the best option to conduct trending analysis. Salvi Del Pero acknowledged that conducting such surveys is challenging.

Cohoon suggested that it is important to look at trends over time and at different levels. She presumes that OECD will discover shifts in female participation or female interest that occur simultaneously across levels to determine the extent to which the “pipeline” metaphor is accurate.

A member of the audience found the motivation data intriguing and inquired whether the definition used in the analysis will be made available. She added that in developing countries recognition of mathematical aptitude is valued more highly than reading. In these cases, the definition of motivation would need to be broadened.

Salvi Del Pero stated that the definition of motivation for this project is based on questions in the PISA survey, which includes a series of questions that ask students to gauge the

importance of a subject to their future studies, career, or advancement. The PISA survey questions are available in any PISA report, but she would send them to Didion to share with the participants.¹¹

Frehill reported that the U.S. Census Bureau recently added “field of study” as a question on the 2009 American Community Survey, which has opened the door to analyzing some of the issues raised in Salvi Del Pero’s presentation. Previously in the United States, the National Science Foundation (NSF) surveys that the Science and Engineering Statistical Analysis System conducted were the only way to examine the connection between college majors and careers. Now, this examination is possible for a wider population. Frehill also asked Salvi Del Pero to elaborate on the type of work being done in relation to gender differences within entrepreneurship.

Salvi Del Pero stated that she did not address the entrepreneurial dimension in the presentation because of time constraints. She acknowledged that work in this area is still in its infancy. In fall 2010, the project team prepared a scope paper outlining the literature relevant to the project. They noticed that no cross-national comparison data were available concerning entrepreneurship. They decided to take advantage of another project initiated by the OECD entrepreneurial indicators program and added a gender dimension to it. They are in the process of collecting these data. Salvi Del Pero was unsure whether the findings would be available to include in their final report.

Discussion Following Ogawa Remarks

During the question and comment session of Ogawa’s presentation, MacLachlan noted one other historical fact: the first woman to receive a Ph.D. in the United States did so around 1888, which was approximately 100 years behind Europe.

Question and Answer Following MacLachlan Remarks

Alice Popejoy from the Association of Women in Science (AWIS) mentioned that AWIS obtained a grant from NSF to explore disciplinary societies. She asked MacLachlan to elaborate on the point she made in the presentation about professional societies and disciplinary societies.

MacLachlan clarified that professional and disciplinary societies had a rather substantial role regarding barriers to women’s participation in chemistry, mathematics, and computer science. When these organizations were established in the United States, most members knew one another (the membership was small). As they grew, they often maintained this club-like characteristic. Therefore, as women became part of the field, they were not always received with enthusiasm. For example, women were not allowed into the University of California, Berkeley faculty association until 1964.

Discussion Following Abreu Remarks

Daryl Chubin, director of the Center for Advancing Science and Engineering Capacity at the American Association for the Advancement of Science commented that Abreu’s presentation regarding horizontal segregation raised interesting measurement issues. He stated

¹¹ To view the sample questions from OECD’s PISA Assessments at: <http://www.oecd.org/pisa/pisaproducts/pisa2000/41943106.pdf>. Accessed August 21, 2012.

that choice and environment are two sides of the same coin, and that researchers will not know enough about environmental constraints by interviewing individuals regarding their choices. Chubin speculated that once Abreu and colleagues establish horizontal segregation in a discipline, they will also discover that it influences the vertical trait. However, he questioned whether “discipline” is the right unit of analysis.

Abreu noted that the literature in this area is extensive. A lot of case studies have been done, especially by anthropologists examining various factors that influence choice of career. She mentioned a highly regarded Brazilian fellowship for which women are underrepresented among recipients. The question of how the fellowship is awarded has been reviewed. She cited one study that revealed that to be considered for the first level of award review women needed to publish four times as much as men, although this was a one-year contextual study. Abreu acknowledged that it is a challenge to illuminate these complex and sometimes invisible social processes.

Chubin followed up by stating that in the United States there is significantly more credibility given to choice than to environmental factors.

Abreu affirmed that it is easier to conclude that gender differences are an outcome of individuals’ choices. It is simpler to regulate solutions to choice because such conclusions do not require any structural change. Unfortunately, she stated, this belief is untrue. For example, Brazil keeps a public database of recipients’ applications. Therefore, anyone is able to compare candidates openly. Transparency is very important to this type of micro-level analysis.

Judy Franz, executive officer emeritus from the American Physical Society and the past secretary general in the International Union of Pure and Applied Physics, commented that she found it most interesting to compare Germany and France, which have similar levels of women’s participation in physics, because cultural distinctions become more evident. She pointed out that questions regarding individual choice and cultural factors have been asked several times in the past.

Abreu agreed that the data are there but suggested that discussion and combating resistance must continue. This is the reason she focuses on institutional processes.

Rebecca Keiser, deputy director of Policy Integration at the National Aeronautics and Space Administration (NASA) acknowledged that the Workforce Sex Segregation and Higher Education presentations raised particular issues for her. She stated that part of NASA’s challenge is the close relationship it has with certain universities. Recruitment is heavily directed toward specific university partners, especially in Florida and Houston. Consequently, the gender inequities at the university level get translated to NASA.

3

Panel II—Focal Disciplines

The three presentations in Panel II addressed the status of women in higher education and the workforce in the three focal disciplines: chemical sciences, computer science, and mathematics and statistics. The first presentation by **Robert Lichter**, a principal at Merrimack Consultants, LLC, focused on the chemical sciences. He found that the percentages of women earning baccalaureate degrees in the chemical sciences were similar in Germany, the United Kingdom, and the United States. For Germany and the United Kingdom, women's representations on the faculty were also similar. He noted that comparable U.S. data were unavailable. In the United Kingdom, Lichter reported that female graduate students were less likely than their male colleagues to indicate plans to pursue a career in the chemical sciences.

Following the above presentation, **Joanne Cohoon**, associate professor at the Department of Science, Technology, and Society at the University of Virginia, discussed the status of women in computer science, focusing primarily on the baccalaureate degree. She addressed the participation of women in computer science compared with their overall participation in higher education in a variety of countries. Her examination of women's participation in the computing workforces showed recent decline in India, Spain, and the United States. She concluded that women's participation in computer science may be linked to cultural stereotypes about gender.

The final presentation by **Keith Crank**, the research and graduate education manager at the American Statistical Association, and **Ingrid Daubechies**, professor at Duke University and president of the International Mathematical Union, concentrated on women in graduate education and the workforce in mathematics and statistics. Crank noted that European women earned roughly half of the graduate degrees compared with approximately 40 percent of women in the United States. He found gender differences in subdisciplines, females being more likely than males to be in statistics. In terms of the academic workforce, Crank reported that women were better represented on the faculties of master- and bachelor-level institutions. Daubechies spoke further on the challenges of motivating women to join the mathematics and statistics fields and suggested methods of debunking the myths associated with those disciplines.

3.1 Chemical Sciences¹

Robert Lichter

Merrimack Consultants, LLC

Lichter first thanked his colleagues for their contributions, including Willie Pearson, Jr., Janet Bryant, Lisa J. Borello, and other individuals who were not present but who had contributed to the presentation.

Lichter began his presentation with a motivating argument as to why women in the chemical sciences warranted focused attention. The progress of women in the field lags behind men worldwide with respect to pay, promotion, and advancement to positions of leadership—a critical driver of change. The chemical sciences are often embedded in other disciplines and work settings, and are a key component of a country's ability to maintain global competitiveness. In spite of the highly competitive nature of the field, significant fractions of the population should not be excluded as a potential workforce. Thus, recruitment, retention, and advancement of women in the chemical sciences are critical to all nations.

Robust and reliable data exist for participation of women in chemical sciences in a variety of countries, which are essential for understanding the slow progress of women in the chemical sciences via cross-national and cross-cultural comparisons. Such data are especially critical for creating policies that can advance women in the chemical sciences and, ultimately, to positions of leadership.

Lichter presented data on the percentage of degrees earned by women at the undergraduate and doctoral levels in Germany, the United Kingdom, and the United States. These data showed no significant differences among the three countries: women earned 40-50 percent of the undergraduate degrees and approximately 40 percent of the doctoral degrees. However, looking at women faculty, the percentages dropped to 11 and 12 percent for Germany and the United Kingdom, respectively.

Lichter offered survey data on the career plans of 650 female and male doctoral students in their first and third years of graduate studies (Table 3-1). The results showed that male students' career aspirations were reinforced as they progressed through their studies, so that the percentage of men planning to pursue a career in chemistry increased from 73 to 86 percent between their first and third years, while a substantial drop occurred among women planning careers in chemical sciences, from 85 to 79 percent.

When comparing planned careers in academia or research careers in the chemical sciences, both men and women showed decreased interest in these career paths between their first and third years. The largest drop, from 72 to 37 percent, was observed for women planning research careers, while the drop for men was only 61 to 59 percent.

¹ See Appendix E-5 for the full paper.

TABLE 3-1. Career Choices of Men and Women in the U.K. Chemical Sciences Graduate Programs (in percentage)

	Men		Women	
	1 st Year	3 rd Year	1 st Year	3 rd Year
Planning career in chemistry	73	86	85	79
Planning research in chemistry	61	59	72	37
Planning academic career	44	36	51	33

SOURCE: Royal Society of Chemistry. 2008. *Change of Heart: Career Intentions and the Chemistry Ph.D.* London, U.K.: Royal Society of Chemistry.

To understand these trends qualitatively, Lichter quoted a U.K. female graduate student about her sense of isolation and concern about a lack of appreciation in the field. He indicated that these themes are common in the United States as well. The fundamental issue is one of *perceptions* about possible career choices which are embedded within an environment that is often not seen as welcoming to women.

Finally, Lichter highlighted the lack of disaggregated international data. In many instances, chemistry is not explicitly considered its own field but included more generally with other physical sciences, possibly due to varying definitions of chemistry across sectors and countries. Frequently data are unavailable, particularly from nonacademic sectors, especially industry. Also, data on program outcomes are sparse; in Germany, for example, there are many industrial sector programs between employers and unions that are intended to promote women in chemistry. At the time of the workshop, Lichter and his colleagues had been unable to obtain information on outcomes of these initiatives, which prompted Lichter and his coauthors to expand their data collection efforts to other countries, examining cross-national similarities and differences within chemical sciences compared to other disciplines.

The largest drop, from 72 to 37 percent, was observed for women planning research careers (in chemistry), while the drop for men was only 61 to 59 percent.

—Robert Lichter

3.2 Computer Science²

Joanne Cohoon
University of Virginia

Cohoon presented data on entry-level degrees (bachelor's degrees) and workforce trends in a few selected countries to address the question: How similar or different is women's representation in computer science from one country or culture to another? Cohoon presented Organization for Economic Cooperation and Development data from 33 countries on the percentage of women who earned bachelor's level degrees in computer science in 2008, as shown in Figure 3-1. Women were underrepresented in computer science at the bachelor's level in 33 countries, although the data showed tremendous variation among countries. Slovenia

² See Appendix E-6 for the full paper.

exhibited the lowest relative representation of women at approximately 7 percent, and Greece reported comparatively high representation of women at approximately 40 percent.

Cohoon argued that an analysis of the percentage of women in computer science should take into account the variation across countries in women's overall participation in higher education. She normalized the data by calculating the mean and standard deviation for women's representation in all disciplines in a country; then she compared these calculations with women's representation in computer science (Figure 3-2). The result showed how the representation of women in computer science varied from their representation in all higher education disciplines in each country. In every case, women's participation in computer science lagged behind their participation in higher education, although high variations among countries existed. For example, women's representation in computer science in Turkey (24 percent) varied little from their overall presence in higher education, while in Estonia their 26 percent share of the computer science degrees was notably below all higher education disciplines in the country.

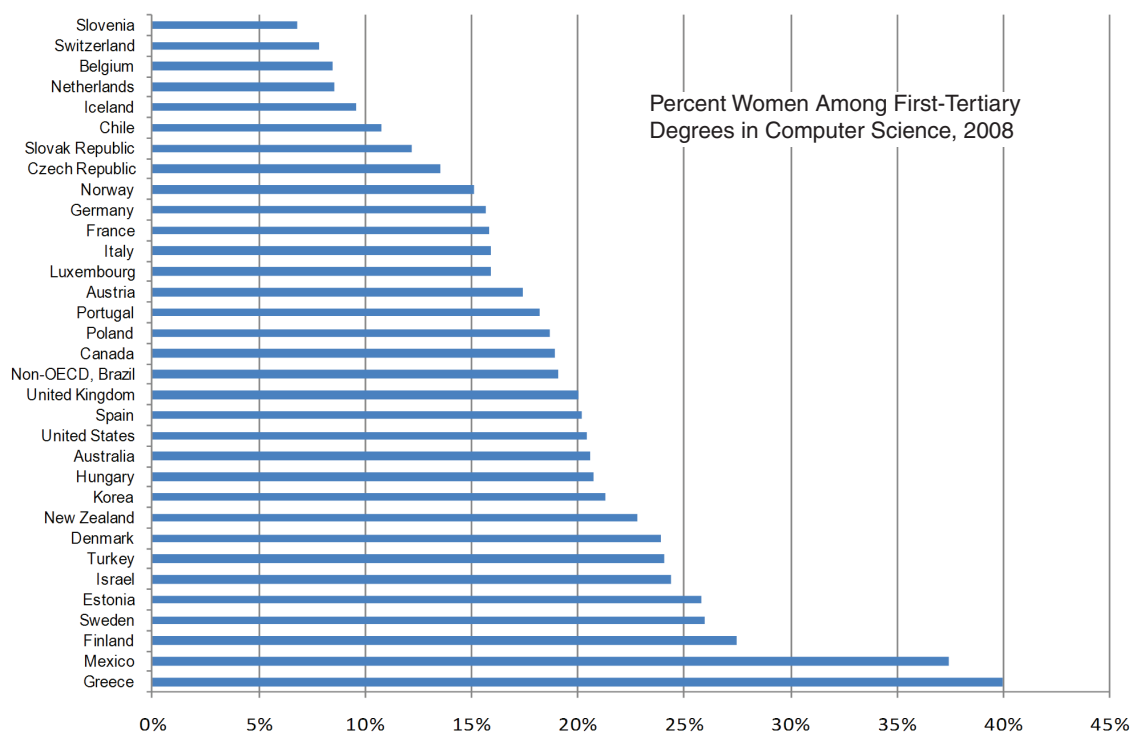


FIGURE 3-1. Women's Representation in Computing Varies across Countries

SOURCE: Organization for Economic Cooperation and Development Education Database. "Computer Science: Cross-National View of Entry Degree and IT Workforce in Selected Countries," presented by Joanne Cohoon at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

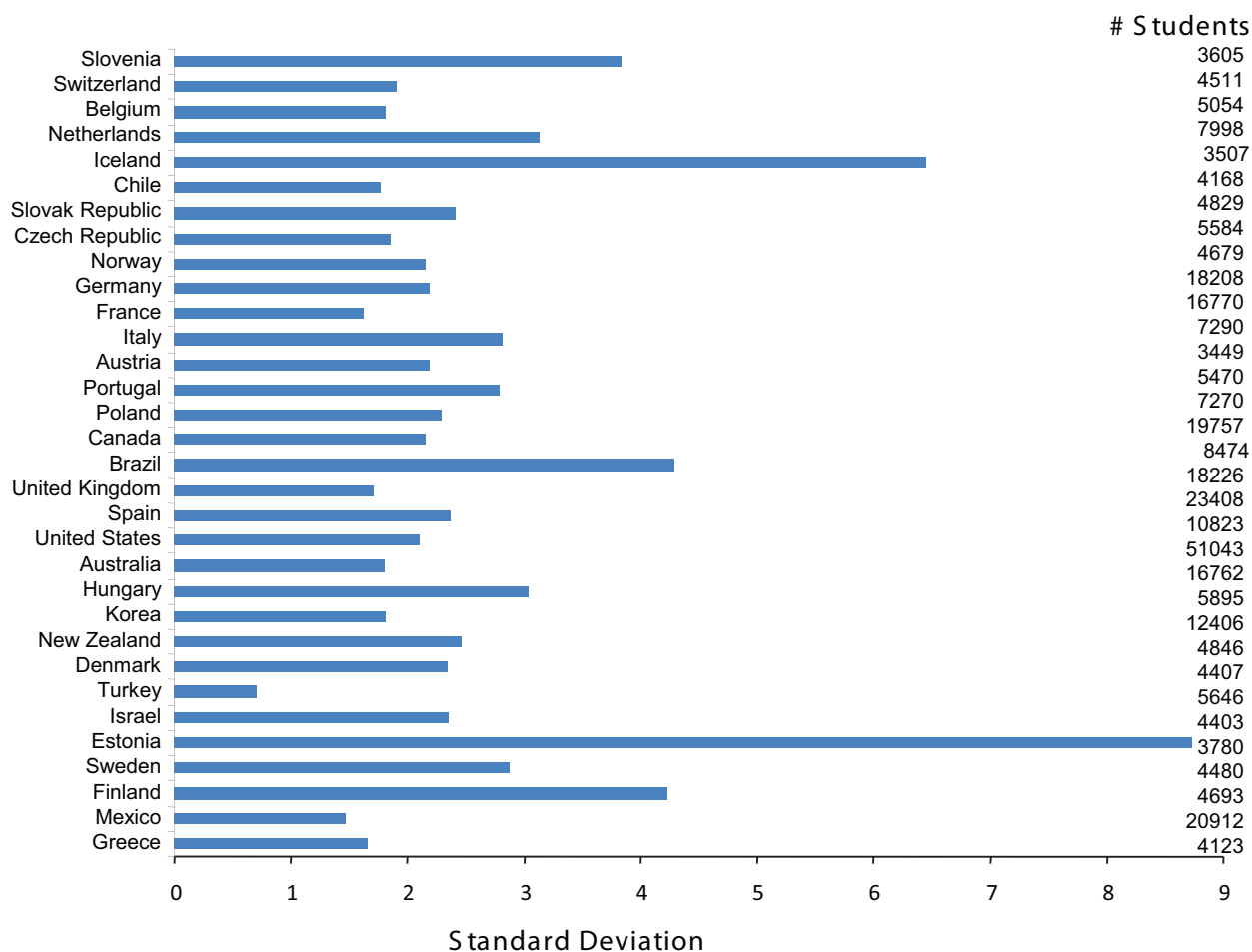


FIGURE 3-2. Women's Share of Tertiary Computing Degrees as Deviation Below Mean Discipline, 2006-2007

SOURCE: Organization for Economic Cooperation and Development Education Database. "Computer Science: Cross-National View of Entry Degree and IT Workforce in Selected Countries," presented by Joanne Cohoon at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

Turning to the workplace, Cohoon described the participation of women in the computing workforce in Brazil, India, Spain, and the United States. In 2009, women comprised approximately 57 percent of the total U.S. workforce but only 30 to 35 percent of the U.S. computing workforce. In addition, the overall percentage of women in U.S. computing occupations declined between 2000 and 2009.

Similar decreases were observed in Spain. Figure 3-3 illustrates women's representation in occupations that required a bachelor's level degree (but not necessarily in computing). Overall, women's representation in computing professions declined from 24 percent to 20 percent between 2000 and 2009. Interestingly, this was at a time when women comprised 65 percent of the entire labor force in Spain. Cohoon noted that women's entry into the labor force in Spain is a relatively recent change; in 2000, women were significantly less well represented.

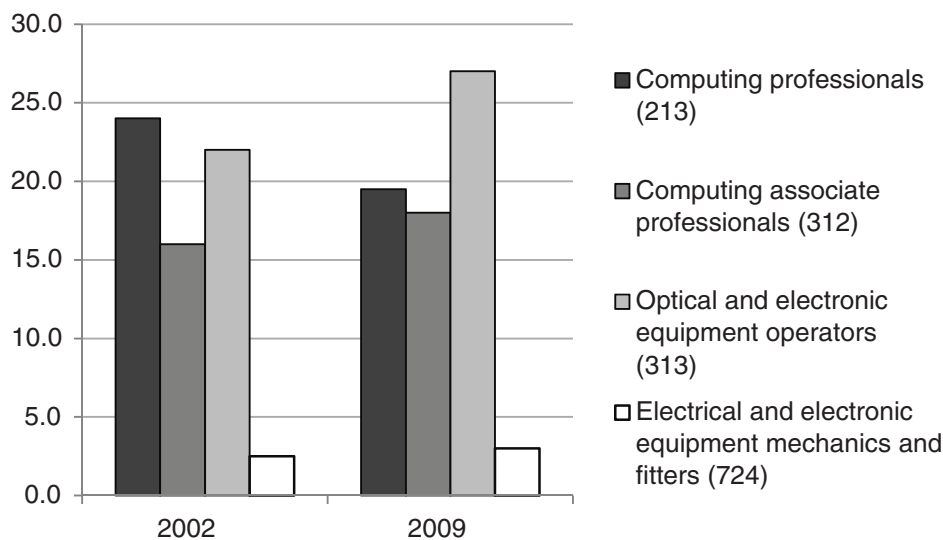


FIGURE 3-3. Women's Share of Spanish Computing Profession, 2002 and 2009

NOTE: Numbers in parentheses stand for International Standard Classification of Occupation Category Code.

SOURCE: Organization for Economic Cooperation and Development data in "Computer Science: Cross-National View of Entry Degree and IT Workforce in Selected Countries," presented by Joanne Cohoon at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

Similar data for Brazil in 2006 indicated that women comprised 20 percent of the computing workforce compared with their overall workforce participation of 42 percent—and 43 percent at the executive position level. In India, data based on a survey of 45 companies revealed that in 2008, women held 36 percent of technical positions in computing professions (although Cohoon noted that some debate exists in the reporting of that number). The number constitutes 3.6 percent of the total female Indian workforce employed in professional- and technical-related positions, similar to the 3.9 percent of the Indian male workforce employed in the same field.

Cohoon concluded her presentation by hypothesizing that the representation of women in computer science may be linked to variations in cultural stereotypes about gender. She posed some questions for additional research: What does it mean to be masculine or feminine in a culture? What stereotypes are there about an occupation and how closely is it aligned with characteristics that are masculine or feminine? In cultures with more essentialist beliefs about men and women (that is, women are close to nature and men are analytical and unemotional), those cultural stereotypes are more likely to align technical and computing occupations to masculine characteristics, leading to an underrepresentation of women. Attention should be paid to how social structures in a country may either facilitate or inhibit those stereotypes.

3.3 Mathematics and Statistics

Keith Crank

American Statistical Association, and

Ingrid Daubechies

Duke University and International Mathematical Union

Crank focused his presentation on graduate degrees, because many jobs in mathematics and statistics require at least a master's degree. He presented U.S. and Eurostat data comparing all (European Union) EU-15 nations, EU-27 nations, and the United States.³ In 2005-2008, approximately 50 percent of the graduate degrees in Europe were awarded to women compared with about 40 percent in the United States.

In Europe, the percentage of female graduate degree recipients in mathematics and statistics is higher than the percentage enrolled, while the opposite is the case in the United States.

—Keith Crank

Similar rates were found in female graduate student participation in the EU-15, the EU-27, and the United States. In 2008, a large number of U.S. students pursued graduate degrees in mathematics and statistics, with women accounting for 40 percent of these graduate students. But U.S. women dropped out of mathematics graduate school programs at a higher rate than men. Figure 3-4 shows the percentage of women among overall graduate degree recipients in all fields and among students enrolled in graduate programs in mathematics and statistics in the United States compared with the EU-27. In the EU-27, the percentage of female degree recipients is consistently higher than that of women enrolled in mathematics and statistics. Except for 2008, the opposite is the case for the United States. What is Europe doing differently that allows more female students to graduate? Crank hypothesized that this variance may be due to different distributions of women in subdisciplines of mathematics and statistics in Europe as compared to the United States.

³ The specific subset of European Union countries constituting the EU-15 are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The EU-27 include those countries listed in the EU-15 as well as Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia.

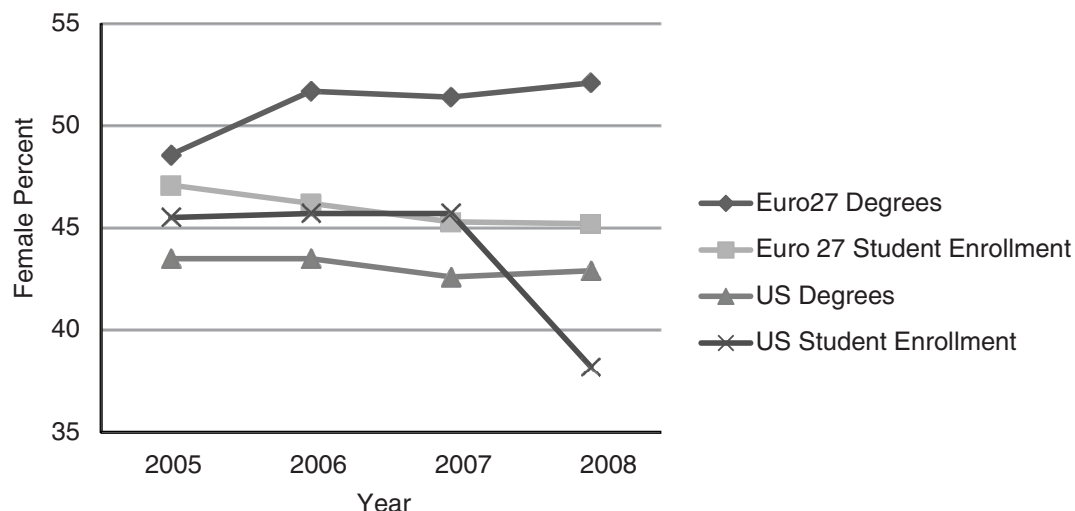


FIGURE 3-4. Comparison of Percentages of Females in Total Student Enrollment with Females in Total Students Who Earned Degrees, 2005-2008

SOURCE: European Commission. Eurostat, 2005-2008.

Crank also presented data from the American Mathematical Society (AMS) on the number of male and female Ph.D. students who earned their degrees in the various subdisciplines of mathematics and statistics, arranged in six groups (Figure 3-5). Males represented the majority in all subdisciplines although nearly half of the degrees in statistics and biostatistics (Group IV) were awarded to women. He speculated that this finding may explain the higher percentage of females awarded graduate degrees in mathematics in Europe, where EU-27 countries as a whole might produce a higher percentage of statistics degrees than the United States.

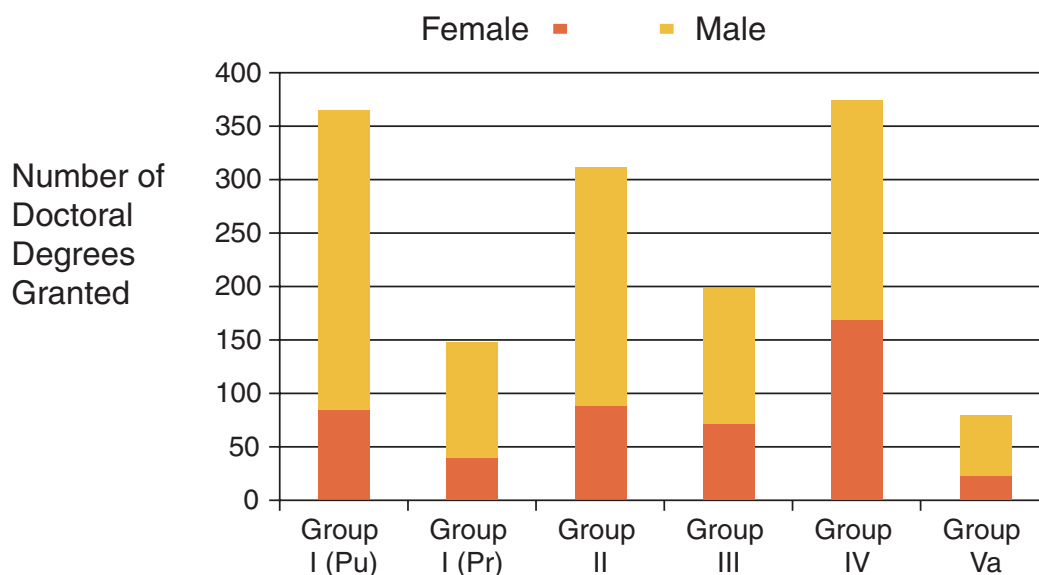


FIGURE 3-5. Gender of Mathematics and Statistics U.S. Doctoral Recipients by Subdiscipline

NOTE: Group I includes 48 doctoral programs in mathematics with quality scores in the 3.00-5.00 range, as determined by the 1995 National Research Council ratings (Pu – Public, Pr – Private).⁴ Group II is composed of 56 mathematics programs with scores in the 2.00-2.99 range. Group III contains the remaining U.S. departments reporting a mathematics doctoral program. Group IV contains doctoral programs in statistics, biostatistics, and biometrics. Group V contains doctoral programs in applied mathematics and applied science.

SOURCE: Cleary, R., J. W. Maxwell, and C. Rose. 2011. Preliminary Report on the 2009-2010 New Doctoral Recipients. *Notices Am. Math. Soc.* 58 (Feb. 2011):294. Reprinted with permission of the American Mathematical Society.

Finally, Crank described the participation of women as faculty members in mathematics and applied mathematics (Groups I, II, III, and V above). Table 3-2 shows the percentage of full-time tenured and tenure-track female faculty in these fields. At all degree levels, women’s representation has improved slightly since 2002.

⁴ National Research Council. 1995. *Research-Doctorate Programs in the United States: Continuity and Change*. Washington, D.C.: National Academies Press.

TABLE 3-2. Number and Percent of Full-time Tenured and Tenure-track Female Faculty in Mathematics and Applied Mathematics by Level of Highest Degree, 2002-2009

	2002	2003	2004	2005	2006	2007	2008	2009
Doctoral programs								
Number	5616	5559	5604	5686	5668	5709	5666	5834
Percent	10	10	11	11	12	12	13	13
Master's only programs								
Number	3188	3005	3113	3351	3400	3325	3403	3208
Percent	22	22	23	24	25	25	26	27

NOTE: Doctoral programs include those in Groups I, II, III, and V (see note in Figure 4-5). Master's only programs consist of U.S. programs granting a master's degree as the highest graduate degree. Bachelor's only programs include all U.S. programs granting a baccalaureate degree only.

SOURCE: Cleary, R., J. W. Maxwell, and C. Rose. 2011. Annual Survey of the Mathematical Sciences in the U.S. (Third Report). *Notices Am. Math. Soc.* 57 (Nov. 2010):1309. Reprinted with permission of the American Mathematical Society.

Crank then turned the presentation over to Daubechies, who discussed the International Mathematical Union's concerns with mathematics education at all levels and its interest in recruiting young people, particularly women, to the field at an earlier age. Daubechies was the director of a program for women in mathematics at the Institute for Advanced Study at Princeton University, which has a number of initiatives intended to improve the situation for women in the field. She noted that the other speakers addressed the need to gather data and offered some theories for the slow progress of women in science. One does not need to understand the phenomenon to make change.

While other fields in the sciences have experienced increased representation of women, Daubechies said, the situation for women in mathematics has not changed much over the years. The "leaking pipeline" problem is compounded in Europe (except Germany) by the inability to attract young people in general. She attributed Germany's success to its outreach efforts, including the sponsorship of an international congress of mathematics, where outreach helped increase the numbers of both women and men in mathematics. She added that emphasizing mathematics as more of an interesting human endeavor seemed to attract more women and young people to the field.

Daubechies asserted that women are frequently told that a scientific career is challenging but rewarding. But young women want to know more about women's careers in mathematics and statistics: Is the work environment enjoyable? Can they make difference in the world? Can they earn a good income? A broader approach in designing activities to engage young women in mathematics is needed. Daubechies concluded by mentioning different global activities, such as a math Olympiad in Europe, intended to increase the interest in mathematics among girls, and efforts by other European nations to conduct studies on the gender gap in the sciences.

3.4 Panel Discussion

Bradley Miller, director, Office of International Activities at the American Chemical Society (ACS), began his presentation by describing several occasions at ACS meetings where he found a “borderless” character to the conduct of research, education, and the practice of chemistry and chemical engineering. He pointed out that young chemical scientists regularly traverse geographic boundaries and that increasingly the country of citizenship, birth, and residence are easily confounded. The ACS International Experiences for Undergraduates, for example, takes students from the United States for a 10-week experience in Europe. Since the program started in 2007, there has been an increase in the number of participants, especially among women (from 40 percent in 2007 to 70 percent in 2011).

Given this increased mobility and increased women’s participation in international research experiences or study abroad programs, Miller posed a number of questions: What is the role of the international experience or study abroad programs? How do they accelerate or hinder productivity and the professional development of women? The ACS program suggests interesting horizontal issues, where students are finding ways to move across borders worldwide and forgo the traditional nation-based training. The question becomes, What is the impact of such training?

Miller then commented on the points raised by Lichter and Daubechies concerning the measurement of impact. Although there are traditional ways to measure scientific productivity, such as manuscripts, citations, patents, and research funding, there are other creative ways to identify impact and success. He recommended measures of mentoring participation, awards and recognition, and leadership in professional associations. There are nontraditional measures of how success in the sciences should be noted.

Allan Fisher, vice president at Laureate Education, Inc., focused on two threads. The first addressed Cohoon’s presentation, which suggested a link between gender and cultural impacts on society. Another set of factors in that equation is the dictum: “Follow the money.” This is related to Anneke Sengers’ observation about women having choices in economically privileged environments. In computer science, for example, although women in the United States are underrepresented, a disproportionate number of women in the field are from developing countries studying abroad. Fisher’s research revealed that many women from developing countries perceived fewer options than the women who began and finished their studies in the United States.

The second theme Fisher addressed stemmed from something he initially learned from Mary Frank Fox’s research: there is a strong correlation between the economic status of a profession and its gender balance. Across nations in Latin America, for example, there is a correlation between the economic development status of the nation and the status of females in some of professions. Fisher also suggested that the perception of quality of life is potentially coupled with the issue of economic choice. This idea presents challenges to institutions, whether universities or corporations or the profession itself: What does the career offer to all the perspective joiners and persisters? Fisher argued that when employers anguish over the shortage of supply of workers, they may find that the shortage is often related to quality of life, work–life balance, attractiveness, or difficulty earning tenure in that profession. He concluded that as much attention should be paid to the supply side as to the demand side of the problem.

3.5 Question and Answer Comments

Discussion Following Lichter Remarks

An audience participant referenced the survey data of women and men doctoral students in the United Kingdom and the drop in female students who were interested in pursuing careers in chemistry (Table 3-1), asking how much of the decline reflects a lack of role models. Lichter clarified that the data were extracted from a single survey from a larger report, which indicated that respondents reported a lack of feedback from advisors. Also, the structure of doctoral study may have contributed to a sense of isolation. In Britain, unlike the United States, students work independently and often are not part of a research group, so they may not have a sense of community. The women perceive that no one is there for them.

Anneke Sengers from the InterAmerican Network of Academies of Sciences suggested that the work–life balance is a great luxury for women in developed countries. She clarified that women in developed countries now have choices. Perhaps such a woman can work half-time or has a husband to support her. Women in developing countries generally work all day and as long as they have light, whether or not they have kids. If they do have children, they tie them to their backs so that they can be out in the fields. They do not have a choice. She asked, “Is it an abundance of choice that is doing our women scientists in?”

Lichter agreed that the issue of work–life balance relates to the issue of choice versus environment and culture. He added that this issue of competing demands has been, to some extent, addressed by fellowship programs for students and young faculty that allow them to be paid while dealing with personal obligations.

Discussion Following Cohoon Remarks

Rebecca Taylor, senior adviser in innovation and entrepreneurship, Office of the Science and Technology Adviser to the Secretary in the U.S. Department of State, asked for clarification on the U.S. data. Cohoon responded that she provided the total number of students who earned bachelor’s degrees in the United States; the numbers have fluctuated over the years. Taylor suggested that it would be interesting to track graduates at their first job and then 5 and 10 years later, which might provide insights into how career choices are made *vis-à-vis* the total number of men and women working in the field. Cohoon responded that tracking cohorts is very difficult to implement because of limited data; few studies examine the production of Ph.D.s and transitions to academic careers. She is interested in following degree trends at both the undergraduate and graduate levels. She pointed out that in the United States, women’s participation at the Ph.D. level has increased, while it has decreased at the bachelor’s level. She concluded that it may be much less a pipeline issue and more an issue of changing cultural beliefs over times.

Lisa M. Frehill from the National Academies pointed out the existence of data sets that track individuals after they graduate from college. For example, the National Science Foundation’s (NSF) Scientists and Engineers Statistical Analysis System (SESTAT) provides cross-sectional data for U.S. scientists and engineers. The NSF’s Survey of Doctorate Recipients is a longitudinal component of SESTAT and provides data over time about scientists and engineers who hold doctoral degrees from U.S. colleges and universities. The National Center

for Education Statistics' survey program, "Bachelor's and Beyond," is a longitudinal study with data on U.S. college graduates from all fields.

Discussion Following Crank Remarks

Catherine Didion from the National Academies asked whether professional associations and researchers count or define the presented disciplines differently across countries. Crank responded that the AMS probably counts differently than other countries, which can affect cross-national data analysis. He added that the statistics profession in the United States has been working hard and long to convince the public that they are not mathematicians. Crank explained that, in the United Kingdom, statistics is usually within a department of mathematics but that students in these countries go on to become research statisticians of some prominence.

Discussion Following Panel Discussion

Zakya Kafafi of NSF commented on the metrics cited during Daubechies' presentation, in which she showed data from the Association for Women in Mathematics. Although the Institute for Advanced Study started in 1994, the data shown were only from 2000 and 2006; Kafafi added it would be interesting to follow the careers of women to best monitor their progress. Daubechies agreed and said the challenge is to prove that the Institute made a difference. She said that she needed comparative data that included career outcomes of those who completed and did not complete the Institute program. Kafafi suggested that progress alone would be good indicator. Frehill added that Daubechies should use the longitudinal data in the Survey of Doctorate Recipients from NSF.

Kaye Husbands Fealing, from the Committee on National Statistics at the National Academies, pointed out that there is some literature that follows cohorts over time, which could provide an appropriate model. She suggested that it is useful to think about what is coming down the road in terms of the demand for new areas of exploration in the sciences and then think about what should be the share of women in these areas. She observed that the previous presentations did not mention wage and salary. Fealing said that she is interested in examining critical degree-level transitions (B.S. to M.S. to Ph.D.), especially focusing on the ebbs and flows of percentages of women and men. This issue raises questions about the experimental side, the nominal impact of wage and salary, and how that affects women's participation.

Lichter thanked Miller for raising the issue of evaluation. He explained that the measurement of impact is an undercurrent of the chemical sciences research team's work. He argued that there is a tendency to confuse outputs with outcomes and called for more research on outcomes and impact.

Panel III—Cross-Cutting Themes

Panel III focused on cross-cutting themes associated with women in science in a global context with three presentations: **Lisa M. Frehill**, senior program officer at the National Academies, discussed the roles of disciplinary societies in advancing women in the sciences; **Daryl Chubin**, director of the Center for Advancing Science and Engineering Capacity at American Association for the Advancement of Science (AAAS), described exemplary programs; and **Cheryl B. Leggon**, associate professor at the School of Public Policy at Georgia Institute of Technology, in collaboration with **Connie L. McNeely**, professor of public policy at George Mason University, addressed policies that are presumed to be effective in enhancing women's participation in sciences in a global context. The themes raised were expected to serve as catalysts for future research and programmatic efforts.

4.1 Role of Disciplinary Societies¹

Lisa M. Frehill

The National Academies

Frehill began her presentation on the role of disciplinary societies² in the status of women in the chemical sciences, computer science, and mathematics and statistics by introducing the theoretical foundations related to the emergence and development of disciplinary societies. Social theorists such as Georg Simmer, Max Weber, Emile Durkheim, and Karl Marx called attention to the functions of societal institutions and considered social networks as both a consequence and a potential source of large-scale societal change. In this context, the general functions of disciplinary societies include socializing new members, enabling collective actions of the members, and engaging in an array of normative functions, such as regulation of a profession or professional practices. Conferences, research, journals, community networking, policy work, and scholarships and awards are all mechanisms for implementing those important functions and for allocating resources.

The geographic scope of disciplinary societies can affect the extent to which they may become involved in policy and political issues. For example, the International Council for Science (ICSU), which has 113 multidisciplinary national scientific members, associations, and observers, is a federation of many smaller organizations. Such a structure has enabled ICSU to reach across a wide geographic spectrum in both soliciting information and calling for actions.

¹ See Appendix E-7 for the full paper.

² The term “disciplinary society” rather than “professional society” is used in this summary because in some international contexts the term “professional society” connotes a specific normative framework, that is, performing state functions of licensing or other certification of members.

In addition, Frehill explained that the organizational structure and governance of disciplinary societies affect the extent to which they might engage in actions to promote diversity. One can better understand the functions and mechanisms used by associations to address members' ethnic, racial, and professional identities by understanding each society's collective identity. For example, some efforts to promote diversity are organized under the umbrella of a larger disciplinary society, such as the Women's Chemists Committee within the American Chemical Society (ACS). Others are created outside of the existing disciplinary societies, such as the Association for Women in Science (AWIS). According to Frehill, the location of groups focused on gender, ethnic, or racial issues "may have to do with the receptivity or non-receptivity or the extent to which folks from these groups had a legitimate community within the larger professional society." At the international and regional levels, the emergence and development of groups focused on diversity have also occurred but the time frames vary across countries.

Frehill concluded by emphasizing that "disciplinary associations are an important organizational structure through which scientists build communities of practices, reward achievements, and enable members to share information."

4.2 Promising Programs³

Daryl Chubin

American Association for the Advancement of Science

Chubin spoke on behalf of his coauthors, Catherine Didion, Josephine Beoku-Betts, and Jann Adams. He began by providing an overview of a public-private partnership known as BEST (Building Engineering and Science Talent), which evaluated 124 U.S.-based, undergraduate-centered STEM⁴ programs and produced a report. On the basis of available evidence, the programs were sorted into three categories: exemplary, promising, and not ready. The report identified major principles to consider when looking across programs:

- national or local cultural context matters
- sponsors, program organizers, and target populations may bring different expectations to the program
- program design may differ from its implementation
- program evolution and its "life cycle" need to be captured
- programs need to be adapted and scaled to new contexts and new populations

Chubin also gave a short list of program selection criteria, noting that exemplary programs met the following six requirements:

1. Specified forms of intervention for more than one kind of activity.
2. Specified an age, or stage, of the target population.
3. In operation for more than 5 years to signal the prospect of institutional sustainability.
4. Provided evidence of positive outcomes, as documented by third-party monitoring, evaluation, or research studies with comparison groups.

³ See Appendix E-8 for the full paper.

⁴ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

5. Provided findings that inform the implementation of similar programs.
6. Demonstrated modification of program operations over time that result from data-based feedback.

Less than 10 percent of the nominated programs in the BEST population met all of these criteria. He emphasized that if an intervention program is successful, it will eventually move from the margins to the mainstream of the organization's mission.

To demonstrate variations across cultures, Chubin presented case studies of two successful programs, one from the developing world, the Organization for Women in Science for the Developing World (OWSDW)⁵, and the other from the developed world, the U.S. National Science Foundation (NSF)'s ADVANCE Program.⁶ He briefly described the OWSDW Postgraduate Training Fellowship Program, which was established in 1998 and has funded women scientists under the age of 40 to help secure postgraduate training in the global south (southern hemisphere). Although the impact is uneven geographically (with a larger impact in the African region), Chubin suggested that the program has successfully launched careers of women scientists, generating south-to-south exchanges, and stemming, to some extent, the problem of "brain drain" to the north.

The second case study was NSF's ADVANCE program, which is considered the most promising gender-conscious science and engineering faculty-focused program in the United States. Chubin discussed the exemplary ADVANCE programs at the University of Michigan and the University of Wisconsin, which through a series of initiatives increased the number of hired tenure-track women faculty and staged a series of interventions by the faculty and division heads to improve the "climate." Overall, the ADVANCE program focuses on institutional transformation, which Chubin suggests should lead to larger structural changes.

He concluded by emphasizing the importance of the program "life cycle" and what can be done beyond understanding it. Institutional changes should be applied to similar programs at other sites, where practices and program structures can also be spread and scaled. However, Chubin acknowledged that additional research is necessary to account for the critical role of varying perspectives and the need to fit efforts into specific contextual situations.

4.3 Promising Policies⁷

Cheryl B. Leggon
Georgia Institute of Technology, and
Connie L. McNeely
George Mason University

Leggon and McNeely presented an examination of promising policies for advancing women in science. Leggon began by conceptualizing "policy" in three ways. First, think of policy as a plan of action, where "policy does not exist in a vacuum, but rather within a context of political, economic, social and cultural forces. Policy is not static. It's dynamic and should be

⁵ The OWSDW was formerly known as the Third World Organization for Women in Science. For more information, please see: <http://owsdw.ictp.it/>. Accessed on August 22, 2012.

⁶ ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers. For more information, please see: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383. Accessed on August 22, 2012.

⁷ See Appendix E-9 for the full paper.

structured in such a way to make adaptations when warranted.” Second, conceptualize policy as a line of argument, which rationalizes a course of action or inaction: “Within the context of women in science, an example of this approach would be shifting the way the argument and issues are framed from that of social justice to national development.” Finally, consider policy as an intervention, where policy changes outcomes that are perceived as undesirable. In all three cases, she emphasized the need for data that can be appropriately disaggregated by gender, race, ethnicity, and region to provide a clear picture to drive and inform policies across nations.

Leggon then presented an overview of the characteristics of promising policies that were derived from the BEST initiative.⁸

- A policy should be driven and informed by data and information that are credible, reliable, and valid.
- A problem or issue is clearly identified and specified to maximize effectiveness of the policy.
- The most promising programs need to be coupled with policy statements and with policy implementation.
- Policy statements should specify goals, objectives, and guidelines. Objectives, along with clear guidelines, establish targets instead of quotas for policy actions.
- Gender mainstreaming is a strategy for assessing the implication for women and men of policies and programs.
- Policies are expected to be sustained and institutionalized. Once a policy is institutionalized, issues of gender and science become criteria by which the performance of a nation, institution, or individual will be assessed.
- Certain processes and principles should be identified and applied across geographic boundaries and disciplinary boundaries, often referred to as diffusion.

Leggon discussed the analytical dimensions that are reflected in substance and actions at different levels, noting that efforts at regional, national, and international levels may intersect. Often the intersection occurs when a national organization belongs to a regional organization or when either institution belongs to a broader international organization, which forms direct connections among levels. Figure 4-1 briefly portrays an example of how national, regional, and international intersections arise. Specifically, organizations may intersect when policies of one institution are adopted by others, with the organization at the international level strategically positioned to leverage the greatest reach. In this case, individual organizations do not necessarily need to reinvent the wheel because the ground work for ideas, agenda setting, formulation, and implementation of policies has often been laid. International and regional organizations can also provide external legitimacy to bolster arguments for the enactment of policies.

⁸ Outlined by Chubin in Section 4.2 and Appendix E-8.

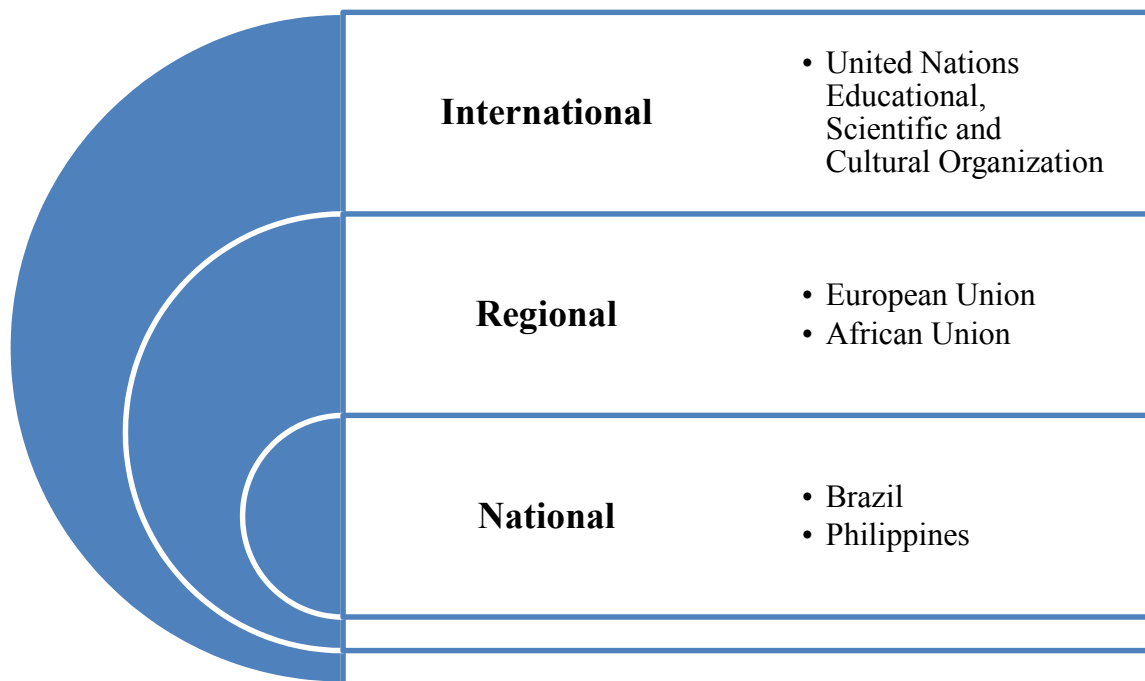


FIGURE 4-1. Examples of the Relationships among Institutions at Different Levels

SOURCE: The “Promising Policies” presentation made by Cheryl Leggon at the Blueprint for the Future: Framing the Issues of Women in Science in a Global Context Workshop.

Although there is general agreement that no country can afford to exclude more than half of its population from its STEM education and workforce, Leggon explained, several challenges remain that impede women’s advancement. These include raising awareness and transforming gender attitudes to remove societal and cultural barriers, and emphasizing the importance for all stakeholders to be actively involved in sustaining, mainstreaming, and institutionalizing policies.

4.4 Panel Discussion

Several discussants shared their experience and comments in this session. **Jessie DeAro**, program director in the Education and Human Resources Directorate at NSF, spoke about the value of further study on promising programs and promising policies from the funding agencies’ standpoint. She suggested that the program directors look into historical information about the institutions and professional societies and explore more about critical leverage points for program interventions. DeAro mentioned that NSF has the complicated task of supporting projects with ongoing and demonstrated positive results, as well as supporting projects that are more innovative. It would be helpful if research could provide suggestions on the leverage points for funding agencies’ investments within their budget limitations. DeAro acknowledged “the unique values women have brought to science and engineering, which are relatively new, but which clash with the historical way that science has been done. [It] would be interesting to pull that out and identify those values and how they can contribute to the vitality and

productivity in science and engineering in a different way than traditional science and engineering, which may be more competitive, less collaborative.”

Kathie Bailey-Mathae, director of the Board on International Scientific Organizations at the National Academies, commented on the different structures of organizations at different levels, as discussed by Leggon, which can present both challenges and opportunities. Many of the U.S.-based professional organizations have individual members, and most of the international organizations have national members. There are numerous ways that the United States can be involved with women and capacity-building programs through societies and unions. Organizations at different levels can, and often are, working on the same issues. Bailey-Mathae noted the importance of all of them working together. She also raised the issue of the challenges (e.g., access to education and good mentors) faced by women in developing countries; many of these challenges are very different from those faced by women in developed countries, and they are not always fully addressed by international policy.

Patricia Taboada-Serrano, early-career representative of the Women for Science Working Group from the InterAmerican Network of Academies of Sciences (IANAS), introduced the IANAS agenda. The agenda focuses on encouraging each country’s national academy to start its own programs and to bring the gender issue to its programs, institutional structures, and cultures. She concurred that the data gathering and discussion of different factors affecting women’s equity and advancement at the workshop will help to identify issues that influence women’s advancement in science and engineering in general, as well as to identify issues specific to several disciplines. Going back to policies and programs, Taboada-Serrano stated that the challenge is more than changing numbers. The broader vision, she noted, is to change cultures and mindsets.

4.5 Question and Answer Comments

Discussion Following Frehill Remarks

Joanne Cohoon from the University of Virginia asked whether women’s committees within many organizations and institutions are more beneficial to networking opportunities and peer support than free-standing entities that are exclusively for women. Frehill responded that measuring the effects of these women’s committees is often challenging. She gave an example of a mentoring program, which had been mentioned earlier by a workshop participant from the Association of Women in Mathematics. Although such mentoring programs were often set up at a grassroots level, it was not always clear whether the participants received similar mentoring at their own institutions or whether the program supplemented that mentoring. This lack of clarity underscores the need to drill down and examine these programs very carefully. Frehill discussed the importance of maintaining program control by women at the grassroots level. If a program with demonstrated success was then run by a parent society rather than its women’s subgroup, it was difficult to know to what extent it would continue to have the same effectiveness for the participants. If the program continued to be run at the grassroots level and received dedicated resources from the parent society, the program may retain its character.

Judy Franz, executive officer emeritus from American Physical Society (APS) and the past secretary general of the International Union of Pure and Applied Physics (IUPAP), spoke about APS practices that kept women within the organization instead of starting a new society. It is sometimes difficult for large international groups to focus on specific tasks, but it is easier

for disciplinary unions that belong to those international groups to make an impact. Franz reported that IUPAP passed a resolution that all of its conferences must include women on committees that select speakers and have women as invited speakers.⁹ Frehill applauded this action, agreeing that institutions and societies in physics have done much international work and could serve as a model for other disciplines.

Janet Bryant, a scientist and engineer at the Pacific Northwest National Laboratory, shared information about the ACS's Women Chemists Committee, which was set up 85 years ago and now is a part of the governance structure of the ACS. One good model was the recent formation of a joint subcommittee on diversity that grew from a grassroots effort by several ACS affinity groups focused on individuals' characteristics (gender, ethnicity, and disability status). The joint subcommittee is now sanctioned at the technical society level, which has more power within ACS than do the separate affinity groups. Also, ACS is having a great impact on outreach in collaboration with the IUPAP and the United Nations Educational, Scientific and Cultural Organization, and particularly in outreach among sister societies for the 2011 International Year of Chemistry.

Discussion Following Chubin Remarks

Ingrid Daubechies from the International Mathematical Union expressed concern about the difficulty of making big institutional changes, suggesting that it might be more effective to extract principles and to inspire small programs. Chubin pointed out that scaling was feasible because guidelines can help individuals stay on the path to change. Given constraints in organizations, such as different cultures and contexts, he and his coauthors suggested using the word "adaptation" instead of "adoption." He pointed out the need for better mechanisms of information sharing across institutions.

Cphoon mentioned that because intervention programs are often a special add-on to a targeted population, they tend not to be well-supported. She questioned whether it was possible for any program to be effective in the long term if it was putting a bandage on a problem, while the overall structure may have serious problems. Chubin responded that if the add-on is effective with a particular population, it could be incorporated into mainstream institutional practices.

Shirley Malcom, head of the Directorate for Education and Human Resources Programs at AAAS, mentioned that Uri Triesman¹⁰ questioned the idea of having a special program for minorities, because, in some cases, people who are not well-served are also in the majority. How is program spending justified? Chubin responded that he does not have a good answer. He noted that this question is about what happens when a program matures. As institutional culture changes over time, the original rationale for the program, which had been grounded in a now-out-of-date set of circumstances, may no longer fit the current culture.

⁹ Hartline, B. K. and D. Li, eds. 2002. "Women in Physics." The International Union of Pure and Applied Physics International Conference on Women in Physics. March 7-9; Paris, France. New York: AIP Conference Proceedings.

¹⁰ Uri Treisman is professor of mathematics and director of the Charles A. Dana Center at the University of Texas at Austin. Treisman was named a MacArthur Fellow in 1992 and was named as one of the outstanding leaders of higher education in the 20th century by the magazine *Black Issues in Higher Education* in December 1999.

Discussion Following Leggon Remarks

Franz said that Leggon phrased the issue effectively: “It’s not the women who need to be fixed. It is the men who need to be fixed.” She voiced a need to have more discussion on making cultural changes as well as better phrasing of the gender issue. It is very important for women scientists to find a better way to carry and deliver their message through scientific organizations.

The big challenge overall ... is the reaction of nonwestern countries when western countries develop a policy, then expect nonwestern countries to implement it.

–Rebecca Keiser

Rebecca Keiser, deputy director at the National Aeronautics and Space Administration concurred that Leggon’s presentation effectively put the emphasis on evaluation, and on making policy data driven. She noted that, at the international level, not all entities change policy at the same time. Changing policies is challenged at the stages of policy formation and policy implementation. International policy embodies

power differences, Keiser cautioned: “the big challenge overall that we are all aware of, but have to continue to be aware of, is the reaction of nonwestern countries when western countries develop a policy, then expect nonwestern countries to implement it... Those differences in power are essential with policy” and should be considered. Leggon agreed that “one size does not fit all”; however, she noted that there are certain principles (e.g., coupling gender issues with national development) that can be transferred to different geographic areas. Promising policies can also be transferred and may be helpful to identify the issues and to build upon what others have learned.

Joan Goldberg, executive director of the American Society for Cell Biology, commented on the Panel III discussion. She noted that many programs at the institutional level do not have control groups, and the data from evaluation, if they exist, are not always helpful. In addition, it is important to think about the language we use to describe diversity and gender issues. She suggested using a more discriminating mind to think about the language, targets, and benchmarks we use. Leggon responded that this lack of clarity is why there is a need to emphasize the importance of disaggregating data appropriately within a given institutional context.

Discussion Following Panel Discussion

McNeely agreed with Taboada-Serrano’s point about changing culture, confirming that it is important to take the inherent tension and dynamics of cultures into consideration. In terms of data collection, women are not a monolithic group, so there is a need for data that drills down. In other words, data should not be considered only horizontal but also vertical in multicultural societies. The problem of the double bind for women of color in the United States exists elsewhere too. Carefully posed questions can enable researchers to better differentiate the underlying dynamics associated with these processes. McNeely suggested that we engage in more complicated data collection. DeAro agreed with McNeely’s point about data collection, noting that potential issues that can be added to the discussion are mobility of faculty and the presence of foreign-born and foreign-trained faculty. These complicate gender issues because faculty members come from different cultures, and their mindsets vary greatly across cultures.

Robert Lichter from Merrimack Consulting, LLC, pointed out that one voice workshop participants had not heard from is the voice of employers (e.g., in industry) who are significant in the “gender” conversation. **Jane Prey**, the senior research program manager at Microsoft Research, responded to Lichter’s comment. She discussed her professional experience working on the strategy for gender diversity and research at Microsoft and the difficulties in motivating employees to buy in.

I sold [gender diversity at Microsoft] as a business case. I redid all my information and sold it as a business case. [Afterward], I had people, men, come up to me and say, ‘I get it! I actually understand why we think this will be important.’

–Jane Prey

However, opinions changed after she reworked her gender diversity pitch. “I sold it as a business case. I redid all my information and sold it as a business case. [Afterward], I had people, *men*, come up to me and say, ‘I get it! I actually understand why we think this will be important.’” Prey emphasized that phrasing diversity strategy as a business case makes it much more salable. McNeely concurred and noted that strategically shifting the way people frame the message makes people feel they have some kind of investment.

Alice Popejoy, the public policy fellow from AWIS, followed up on the discussion on messaging, observing that “messaging is not about what is right but about what is smart.” Sending the message smartly is not only to get politicians’ buy-in, but it is also to adjust women’s perspectives on the gender issue, because women sometimes have the same bias as men against women in science. Research demonstrates that having one or two women on an award selection committee does not actually improve the number of women getting awards, but having a woman chair the committee does make a difference. In addition, it is important to engage leadership while implementing policies and programs in disciplinary societies. Popejoy pointed out that disciplinary societies and academic institutions have usually been given general guidelines to implement better practices. However, given the different cultures and issues within the disciplines and societies, it is important that their leadership enables change rather than placing the responsibility for change solely on committees that are dedicated to women’s issues.

Cohoon also commented on messaging and how messages are framed. She noted that a review of successful social movements revealed that a critical part of the process was to shift the argument away from the personal to the political. Making the moral argument is an important step toward achieving the success of a social movement.

CONCLUDING PRESENTATION AND DISCUSSION

Shirley Malcom, head of the Directorate for Education and Human Resources Programs at the American Association for the Advancement of Science (AAAS), led the concluding discussion at the workshop. Malcom started by sharing her work as a U.S. public delegate for the 2011 United Nations (UN) Commission on the Status of Women, where she was charged with infusing the status of women in science and technology into the gender-based discussions. At both this and the 1999 UN World Conference on Science, people did not see the connection between science and technology and gender. In order to promote gender diversity in science and technology, Malcom concluded, the language used to promote initiatives may need to be changed to connect most effectively with the decision-making audiences. In other words, the “wrapper” or packaging of the issues becomes exceedingly important. Refraining from using broad terms such as “gender mainstreaming” is imperative. Rather, Malcom urged the use of formal analysis to determine the impact of decisions on both men and women. She emphasized, “It’s not just about one [gender] or the other, but it’s both. It’s basically an understanding that if there is a different impact, what does it look like? ... And is this in the end going to make a positive difference on this society?”

Malcom noted that many nonwestern countries’ gender policies are significantly more advanced than in the United States and with a higher level of tolerance. For example, many countries have sex quotas in governance. In many cases, these countries emerged out of revolutions in which women played an active part, so women were incorporated into the post-revolution governance structure. After the genocide tragedy in Rwanda, the next parliament consisted of over 50 percent women. This percentage was achieved partly through the sex quota system and partly through women running for regular (non-quota) seats in the government. Women were the majority in the country, and economic development necessitated policies that treated women equitably.

She discussed how to justify special projects for minority groups to the majority in power and how to implement change. If the program does not work well for women and minorities, it may not work for the majority either, although it may not be obvious that it does not work well. Malcom described a calculus project that Uri Treisman created to promote individualized instruction. Initially, the program worked to increase minority success in calculus but was eventually shown to improve all students’ success, regardless of status. Instead of trying to focus solely on minorities, the calculus project changed the system overall, which benefited everyone.

Malcom also spoke on the leadership changes in her own organization. After cracking the glass ceiling by having the first woman president of AAAS, approximately 40 percent of subsequent presidents have been women. Malcom suggested that, based on her experience, the challenge is often the advancement of only one woman to a high-level position; after one woman advances, other institutional changes follow organically. In the case of AAAS, a female president

made a difference for many reasons. Her presence helped to change the norms of the organization, if not the normative behavior of its members. As the gender composition of the AAAS membership changed to include more females, the priorities and interests of the new members had a significant impact on the organization. The larger female membership base also facilitated access to more talent to fill higher leadership positions, which improved the gender diversity in leadership roles and encouraged change in the organization.

To effectively increase gender diversity in science and technology, the role of data is critical: “We cannot operate off of what we do not know.” She called for data that are disaggregated by field, subfield, race, sex, and geographical location. With appropriate data disaggregation, a clear understanding of why diversity issues are different in one location compared with another will arise and lead to informed action.

Many organizations, such as Asia-Pacific Economic Cooperation and the United Nations Educational, Scientific, Cultural Organization (UNESCO), have advocated for disaggregated data, as have countries such as Brazil and South Africa that have historical issues related to minority advancement. However, it seems to be more difficult to get disaggregated data from some European countries where there appears to be current ethnic equity problems, and governments do not want to deal with these problems.

Malcom also commented on the discussion concerning career “choice” and “interest.” The term “choice” does not always apply in cross-national contexts, and new ways of thinking or new terminology may be necessary. “We have been living in a context where the jobs and the education have been structured to fit males’ lives. So what does that [structure] look like ... if we imagined the lives of people who want to have a life? I think that imagining a different kind of context is what is hanging us up. We have the current models and we cannot imagine other models.”

She noted that in many cases imagining a new and different model was restricted by the belief that the current model is correct, or is the only model. For example, Malcom argued a case for the possibility of half-time jobs and half-time tenured positions, which would challenge structural norms. To encourage diversity, she challenged female scientists and engineers to imagine different structural contexts and make changes proactively. Over time, societies have modified their behavior, such as the networking opportunities formally provided at professional meetings. A good example is that of “smokers.”¹

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–Shirley Malcom

Malcom talked about the GenderInSITE Initiative started by several international groups, including the Organization for Women in Science for the Developing World, the Gender Advisory Board of the UN Commission on Science and Technology for Development, and

¹ “Smokers” were informal gatherings of colleagues to exchange ideas and network. In some cases, faculty at academic institutions would hold “smokers” and, in other cases, they might be held in conjunction with professional meetings. The term “smoker” is derived from the prevalence of smoking as a very common habit in the 1950s–1970s; many of those who attended these meetings were likely to smoke at the meetings. The term also has an intellectual reference to the emergence of ideas, akin to a fire that is stoked by many people.

UNESCO. The Initiative aims to shift the discussion on gender and science and technology to gain broader buy-in and to make clear that major shifts in investments will not be required. Meanwhile, the Initiative seeks to make gender discussions important to policy-makers and business leaders in many countries worldwide.

Finally, Malcom challenged participants to look at the changes that have been made and to think about additional ones; programmatic change is necessary for long-term structural change. There is still ignorance about potentially promising institutional changes, witnessed by recent debates over a 1999 report on the status of female faculty in the School of Science and Engineering at the Massachusetts Institute of Technology.² Advocates of women's participation in science and engineering need to understand that some beliefs regarding the intellectual inferiority of women still exist. Confronting the bias is always difficult, but women and men should be willing to stand up to it.

The workshop was formally adjourned by **Catherine Didion**, director of Committee of Women in Science, Engineering, and Medicine.

² *Study on the Status of Women Faculty in Science* at Massachusetts Institute of Technology (1999). Available at <http://web.mit.edu/fnl/women/women.html#The Study>. Accessed August 25, 2012.

APPENDIX A

Workshop Agenda

<p><i>Blueprint for the Future: Framing the Issues of Women in Science in a Global Context – A Workshop</i></p>

11:30 am – 11:45 am

Welcome and Overview of Workshop

Allan Fisher, Vice President, Laureate Education, Inc., and Member, Committee on Women in Science, Engineering, and Medicine

Carol Stoel, Program Officer, Division of Graduate Education, Education and Human Resources Directorate, National Science Foundation

Catherine Didion, Director, Committee on Women in Science, Engineering, and Medicine

11:45 am – 1:00 pm

Panel I—Cross-Cultural Issues:

- Knowledge and Data Sources
Wendy Hansen, Senior Researcher, University of Maastricht
Angelica Salvi Del Pero, Administrator (Gender) Social Policy Division, Directorate for Employment, Labour and Social Affairs, Organization for Economic Cooperation and Development
- Socio-Historical Trends
Mariko Ogawa, Professor, History of Science and Science Studies, Mie University, Japan
- Higher Education
Anne MacLachlan, Senior Researcher, Center for Studies in Higher Education, University of California, Berkeley
Cheryl Leggon, Associate Professor, School of Public Policy, Georgia Institute of Technology
- Workforce Segregation
Alice Abreu, Regional Coordinator, Rio+20 Initiative, International Council for Science

Discussant: *Anneke Sengers*, Scientist Emeritus, National Institute of Standards and Technology and Chair, Working Group on Women, InterAmerican Network of Academies of Sciences

1:00 pm – 2:15 pm

Panel II—Focal Disciplines:

- Chemical Sciences
Robert Lichter, Principal, Merrimack Consultants, LLC
Willie Pearson, Jr., Professor, School of History, Technology, and Society, Georgia Institute of Technology
- Computer Science
Joanne Cohoon, Associate Professor, Science, Technology and Society Department, School of Engineering and Applied Science, University of Virginia
- Mathematics and Statistics
Keith Crank, Assistant Director, Research and Graduate Education, American Statistical Association
Ingrid Daubechies, Professor, Duke University and President, International Mathematical Union

Discussants: *Lilian Wu*, Program Executive, Global University Programs, International Business Machines Corporation, and Chair, Committee on Women in Science, Engineering, and Medicine; *Allan Fisher*, Vice President, Laureate Education Inc., and Member, Committee on Women in Science, Engineering, and Medicine; and *Bradley Miller*, Director, Office of International Activities, American Chemical Society

2:15 pm – 2:30 pm

Break

2:30 pm – 3:45 pm

Panel III—Cross-Cutting Themes:

- Role of Professional Societies
Lisa M. Frehill, Senior Program Officer, the National Research Council
- Promising Programs
Daryl Chubin, Director, Center for Advancing Science and Engineering Capacity, American Association for the Advancement of Science
- Promising Policies
Connie L. McNeely, Professor of Public Policy, and Co-Director, Center for Science and Technology Policy, George Mason University
Cheryl Leggon, Associate Professor, School of Public Policy, Georgia Institute of Technology

Discussants: *Jessie DeAro*, Program Director, Alliances For Graduate Education and the Professoriate, Education and Human

Resources Directorate, National Science Foundation; *Kathie Bailey-Mathae*, Director, Board on International Scientific Organizations, The National Academies; and *Patricia Taboada-Serrano*, Early-Career Representative, Women for Science Working Group, InterAmerican Network of Academies of Sciences

3:45 pm – 4:30 pm

Concluding Discussion

Shirley M. Malcom, Co-Chair, Gender Advisory Board, United Nations Commission on Science and Technology Development, and Head, Education and Human Resources, American Association for the Advancement of Science

4:30 pm

Adjournment

APPENDIX B

Biographies of Speakers

(Biographies provided were those at the time of the workshop.)

Alice R. de P. Abreu is professor emeritus of the Federal University of Rio de Janeiro in Brazil and the regional coordinator of the International Council for Science (ICSU) Rio+20 Initiative. She is the former director of the Regional Office for Latin America and the Caribbean of ICSU ending her mandate in December 2010. She received her doctoral degree in sociology from the University of São Paulo Brazil (1980), and her M.S. in sociology from the London School of Economics and Political Science of the University of London (1971). A full professor of sociology from the Federal University of Rio de Janeiro until 2005, Abreu has published extensively on the sociology of work and gender. She also held a number of important positions within the academic community of Brazil and internationally, which included the vice presidency of the National Research Council for Scientific and Technological Development in the Ministry of Science and Technology of Brazil, and director of the Office of Education, Science and Technology of the Organization of American States, in Washington D.C. Abreu served on the Executive Committee of International Sociological Association for two terms, 2002-2006 and 2006-2010. She received the Ordem Nacional do Mérito Científico (Comendador) of the Science and Technology Ministry, Brazil in 2001; the Palmes Académiques (Officier) of the Ministère de la Jeunesse, de l'Éducation Nationale et de la Recherche, République Française, in 2003. She was awarded the Florestan Fernandes Prize in 2009. Abreu is, since 2010, a foreign member of the Academia de Ciencias Médicas, Físicas y Naturales de Guatemala.

Kathie Bailey-Mathae, director of the Board on International Scientific Organizations (BISO), began her career at the National Academies in February 2005 when she joined BISO as a program officer. After serving as senior program officer and BISO's deputy director, she was appointed director in May 2007. Her responsibilities in BISO have included six U.S. national committees in math and physical sciences, National Academy of Sciences (NAS) representation on the U.S. National Commission for United Nations Educational, Scientific, Cultural Organization (UNESCO), and visa policy. Prior to coming to the National Academies, Bailey-Mathae worked for the Association of American Universities for 14 years. Prior to that, she worked for Congresswoman Lindy Boggs (D-LA) as associate staff for Department of Housing and Urban Development appropriations and special projects assistant. She has a B.A. from Milligan College and a J.D. from Tulane University.

Daryl Chubin became founding director of the Center for Advancing Science and Engineering Capacity at the American Association for the Advancement of Science (AAAS) in August 2004. Prior to that he served more than 3 years as senior vice president Research, Policy and Programs at the National Action Council for Minorities in Engineering, Inc. after nearly 15 years in federal service. Posts included 3 years (1998-2001) as senior policy officer for the

National Science Board of the National Science Foundation (NSF); division director for Research, Evaluation and Communication in NSF's Directorate for Education and Human Resources (1993-1998); and (on detail) assistant director for Social and Behavioral Sciences (and Education) at the White House Office of Science and Technology Policy (1997). He began his federal career in 1986 at the Congressional Office of Technology Assessment. Chubin has also served on the faculty of four universities, including Georgia Institute of Technology, where he was promoted to full professor. Since 1991, he has been an adjunct professor at the Cornell in Washington Program. He has published eight books and numerous policy reports, articles, and commentaries on issues in science policy, human resource development, program evaluation, and engineering education. Among his honors are the following: AAAS fellow, past chair of the AAAS Section on Societal Impacts of Science and Engineering, fellow of the Association for Women in Science, co-recipient of the American Society of Engineering Education Wickenden Award for best paper published in the 2003 volume of the *Journal of Engineering Education*, Quality Education for Minorities/Mathematics, Science, and Engineering 2006 Giant of Science, and Sigma Xi Distinguished Lecturer 2007-2009. Today, he participates on the board of directors of three not-for-profit organizations and on the editorial board of three professional journals. Chubin has a B.A. in sociology from Miami University and a Ph.D. in sociology from Loyola University of Chicago.

Joanne Cohoon is an associate professor at the Department of Science, Technology, and Society at the University of Virginia. She teaches gender, technology, and education and supervises both graduate and undergraduate student research. Cohoon is a sociologist who researches, publishes, and speaks on women's underrepresentation in Information Technology (IT) and on gender segregation in higher education. She has conducted nationwide studies of departmental factors that influence recruitment and retention at the undergraduate and graduate levels of computer science. Cohoon is a senior research scientist at the National Center for Women in IT Social Science Network; and a member of the Georgia Tech College of Computing Diversity Advisory Board, the PROACT Advisory Board, and the Working Committee on Women in Computing of Association for Computing Machinery Committee on Women in Computing. She has a B.A. in philosophy from Ramapo College, New Jersey, an M.A. in student personnel administration in higher education from Columbia University, and a Ph.D. in sociology (dissertation, "Non-Parallel Processing: Gendered Attrition in Academic Computer Science") from the University of Virginia.

Keith Crank is the research and graduate education manager at American Statistical Association (ASA). Prior to joining the ASA, he was a program officer at NSF, primarily in the probability program. Crank has a B.S. in mathematics education, an M.S. in mathematics from Michigan State University, and a Ph.D. in statistics from Purdue University.

Ingrid Daubechies received both her B.S. and Ph.D. degrees (in 1975 and 1980) from the Free University in Brussels, Belgium. She held a research position at the Free University until 1987. From 1987 to 1994, she was a member of the technical staff at AT&T Bell Laboratories, during which time she took leaves to spend 6 months (in 1990) at the University of Michigan and 2 years (1991-1993) at Rutgers University. From 1993 to 2010, Daubechies was a full professor at Princeton University, where she was active especially within the Program in Applied and Computational Mathematics. She was the first female full professor of mathematics at Princeton. In January 2011, she moved to Duke University to serve as a professor of mathematics. Daubechies is the first woman president of the International Mathematical Union (2011-2014). Her research interests focus on the mathematical aspects of time-frequency

analysis, in particular wavelets, as well as applications. The American Mathematical Society (AMS) awarded her a Leroy P. Steele prize for exposition in 1994 for her book *Ten Lectures on Wavelets*, as well as the 1997 Ruth Lyttle Satter Prize. From 1992 to 1997, she was a fellow of the John D. and Catherine T. MacArthur Foundation. She is a member of NAS, AAAS, the AMS, the Mathematical Association of America, the Society for Industrial and Applied Mathematics, and the Institute of Electrical and Electronics Engineers.

Jessie DeAro joined the U.S. Department of Education as a presidential management fellow in 1999 after receiving her doctorate in physical chemistry from the University of California, Santa Barbara. Within the Department of Education, she worked with minority-serving institutions to strengthen the quality of education programs and institutional infrastructure. In 2003, she joined NSF as a program director working with programs to diversify the STEM¹ workforce, including the Historically Black Colleges and Universities-Undergraduate Program and ADVANCE Program. She recently spent a year detailed to the White House Office of Science and Technology Policy where she worked on STEM education and workforce diversity policy. She is once again at NSF working on issues related to graduate education, postdoctoral training, and academic careers, and as program director for the Alliances for Graduate Education and the Professoriate program.

Catherine Didion is the director of the Committee on Women in Science, Engineering, and Medicine (CWSEM) of the National Research Council (NRC). In addition, she is a senior program officer at the National Academy of Engineering (NAE). Her charge at NAE is to provide staff leadership to the Academies' efforts to enhance the diversity of the engineering workforce at all levels. As part of her responsibilities, she is currently the project director for the \$2 million Engineering Equity Extension Service Project, which is working with engineering societies to enhance their gender equity principles within their programs. Before joining the National Academies, Didion was vice president of the Didion Group, a public affairs and communications firm, as well as a director of the International Network of Women in Engineering and Science. Didion previously served 14 years as the executive director of the Association for Women in Science (AWIS). During her tenure, AWIS was awarded the U.S. Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring, and she was the principle investigator for 17 U.S. government and foundation grants. Didion has presented testimony before the U.S. Congress and U.S. federal agencies. She has worked extensively with the European Commission, the South African Ministry of Science and Technology, the Organization of American States, and many other organizations on these issues. She has been an invited speaker on mentoring, networking, and women in science and engineering at over 200 conferences and has authored over 50 publications on women in science and engineering. She was the editor for the "Women in Science" column for the *Journal of College Science Teaching* from 1993 to 2002. Didion has extensive experience on Capitol Hill in Washington, D.C., including staff positions at the U.S. Senate Commerce, Science, and Transportation Committee, the U.S. Senate Computer Center, and the U.S. Senate Press Gallery.

Allan Fisher is the vice president of Laureate Education, Inc. He previously was cofounder, president, and CEO of iCarnegie Inc., an online higher education subsidiary of Carnegie Mellon University; before that, he served until 1999 as faculty member and associate dean for undergraduate education in the School of Computer Science at Carnegie Mellon University. During that time, Fisher worked in high-performance computing and networking research and also led the creation of Carnegie Mellon's B.S. program in computer science. In

¹ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

the late 1990s, he and Jane Margolis carried out a program of research and intervention that helped to increase the proportion of women entering the computer science program from 7 percent in 1995 to 42 percent in 2000. This work is described in their book *Unlocking the Clubhouse: Women in Computing*, published in 2002 by Massachusetts Institute of Technology Press. He received a B.S. in chemistry from Princeton University, studied at the University of Cambridge, and received a Ph.D. in computer science from Carnegie Mellon University. Fisher served on a number of advisory committees for projects and organizations working toward diversity in technology fields, including the Anita Borg Institute and CWSEM.

Lisa M. Frehill is a senior program officer at the National Academies. In addition to her work at the National Academies, she is the director of research, evaluation, and policy at the National Action Council for Minorities in Engineering (NACME). Since earning her doctoral degree, she has developed expertise in the science and engineering workforce with a focus on how gender and ethnicity impact access to careers and international participation and collaboration in these fields. As an associate professor of sociology at New Mexico State University, she was the principal investigator and program director of NSF-funded ADVANCE: Institutional Transformation Program, which sought to increase women's success in academic science and engineering careers. She has consulted with numerous colleges and universities on gender equity issues. Frehill has worked with the Society of Women Engineers on several projects, including a retention study and the annual review of literature on women in engineering. She was the lead author of the Motorola Foundation-funded study released by NACME in 2008 titled "Confronting the 'New' American Dilemma: Underrepresented Minorities in Engineering: A Data-Based Look at Diversity," and the NACME databook. Research in progress includes projects funded by NSF on women's international participation and collaboration in science and engineering and on career outcomes of engineering bachelor's degree recipients.

Wendy Hansen is a senior researcher at the United Nations University Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT). Hansen studied sociology at Carleton University in Canada and joined Statistics Canada's Postsecondary Education Projections/Analyses Section. In the fall of 1988, she moved to Industry Canada, where she has been a senior policy analyst in industry and science policy. Hansen joined MERIT as a senior research associate in May 1997 to continue her research. Her research focuses on knowledge workers, in particular scientists and engineers, and falls in a range of science and technology policy issues and information society. Her research addresses the change in the skill base of the labor force, including the development of new measures for links between knowledge workers and technological change, as well as specific measures of human capital in a digitized society.

Cheryl B. Leggon is an associate professor at the School of Public Policy in the Georgia Institute of Technology. Leggon's research focuses on African American, Mexican American, Puerto Rican, Native American, and Native Pacific Islander women in science and engineering; this focus developed while she was a staff officer in the Office of Scientific and Engineering Personnel at the NRC. Her work underscores the criticality of disaggregating data by race, ethnicity, and gender to develop policy, programs and practices that enhance and expand the science and engineering talent pool in the United States. Currently, Leggon is co-principal investigator on two grants funded by NSF "Inside the Double Bind—A Synthesis of Literature on Women of Color in Science, Technology, Engineering, and Mathematics" and "Cross-Disciplinary Initiative for Minority Women Faculty" (ADVANCE Leadership). She earned a

Ph.D. in sociology from the University of Chicago and a B.A. in sociology from Barnard College, Columbia University.

Robert Lichter, a principal at Merrimack Consultants, LLC, received his A.B. cum laude from Harvard College in 1962 and his Ph.D. from the University of Wisconsin-Madison in 1967, both in chemistry. He was a National Institutes of Health postdoctoral fellow at the Technische Universität Braunschweig, Germany, from 1967 to 1968, and a research fellow at the California Institute of Technology from 1968 to 1970. After 13 years in the chemistry department at Hunter College of the City University of New York, including 4 years as department chair, he became regional director of grants at Research Corporation from 1983 to 1986. From 1986 to 1989, Lichter served as vice provost for research and graduate studies at the State University of New York at Stony Brook. Before embarking on his current position in 2002, he was executive director of the New York City-based Camille and Henry Dreyfus Foundation from 1989 to 2002, where he directed the strategies and administration of 10 programs and related activities that yielded about \$6 million in grants and awards in the chemical and closely related sciences for research, education, science communication, and human resource development. Among his professional activities, Lichter was chair of the AAAS Section on Chemistry for 2001-2002, and was secretary of the section from 2004 to 2009. At the American Chemical Society (ACS), he has been a member of the Committee on Science and its Committee on Minority Affairs, and the latter's subcommittee on the ACS Scholars Program. Lichter has served on and has chaired numerous national panels and advisory boards dealing with broad educational and scientific issues, including many for ACS, NSF, and the NRC.

Anne MacLachlan is a senior researcher at the Center for Studies in Higher Education at the University of California, Berkeley (UCB), and affiliated with the Department of Molecular and Cell Biology as an evaluator of its NSF Research Experiences for Undergraduates (REU) program. She is also the evaluator of a STEM program for underrepresented students at City College of San Francisco. Her research areas for the past 20 years include the issues of access and success of women and minorities in science in postsecondary education from first-year community college students through faculty and leadership positions with a special focus on graduate students. A significant part of this research is on discrimination and bias. She also organizes and gives professional development programs for REU students by drawing on 20 years of experience creating and giving employment and professional development programs for graduate students, postdoctoral fellows, and undergraduates. She is finishing a book on minority success in STEM Ph.D. programs and is developing an institutional evaluation of STEM education in the California community colleges. Her work has been supported by NSF, the Spencer Foundation, and the Max Planck Institute, among others. An example of her service on campus is the Coalition for Excellency and Diversity at UCB, Science Seminar for Underrepresented Minority Graduate Students; as an example of state service, she served with the California Post Secondary Education Commission Gender Gap Project; and for national service, she served as a reviewer for the National Institutes of Health, Sloan Foundation, NSF, AAAS Center for Advancing Science and Engineering Capacity, and Planning Committee for the 3rd Understanding Interventions Conference. A recent talk at UCB was titled "Federal Support for Science in the Research University: The Social Consequences between 1947 and the Present."

Shirley Malcom is head of the Directorate for Education and Human Resources Programs of AAAS. The directorate includes AAAS programs in education, activities for underrepresented groups, and public understanding of science and technology. Malcom serves

on several boards, including the Heinz Endowments and the H. John Heinz III Center for Science, Economics and the Environment, and is an honorary trustee of the American Museum of Natural History. In 2006, she was named co-chair (with Leon Lederman) of the National Science Board's Commission on 21st Century Education in STEM. She serves as a regent of Morgan State University and as a trustee of Caltech. In addition, she has chaired a number of national committees addressing education reform and access to scientific and technical education, careers, and literacy. Malcom is a former trustee of the Carnegie Corporation of New York. She is a fellow of the AAAS and the American Academy of Arts and Sciences. She served on the National Science Board, the policy-making body of NSF from 1994 to 1998; from 1994 to 2001, she served on the President's Committee of Advisors on Science and Technology. Malcom received her doctorate in ecology from Pennsylvania State University; master's degree in zoology from the University of California, Los Angeles; and bachelor's degree with distinction in zoology from the University of Washington. She also holds 15 honorary degrees. In 2003, she received the Public Welfare Medal of NAS, the highest award given by the Academy. Malcom is a member of NAS.

Connie L. McNeely received a Ph.D. in sociology from Stanford University. She is currently professor of public policy and co-director of the Center for Science and Technology Policy at George Mason University. Her teaching and research address various aspects of politics, organizational behavior, science and technology, governance, social theory, and culture. Emphasizing comparative and historical perspectives, her work has engaged questions on international development and organization and on issues related to race, ethnicity, nation, and gender. She also has conducted research on education, science and technology, and health care, and has ongoing projects examining cultural and institutional dynamics and matters of citizenship and polity participation. McNeely is currently working as part of a larger initiative on democratizing education in the United States and elsewhere and is principal investigator on a major research project examining institutional outcomes and policy impacts on women in science, technology, engineering, and mathematics in higher education. She is also active in several professional associations, serves as a reviewer and evaluator in a variety of programs and venues, and sits on several advisory boards and committees.

Bradley Miller, director of the ACS Office of International Activities, has worked for ACS since 1999 developing programs, products, and services to advance chemical sciences through collaborations in Africa, Asia, Europe, Latin America, and the Middle East. At ACS, the world's largest single disciplinary scientific society, he works to create opportunities for chemistry to address global challenges through in-person and Web-based scientific network development and research and educational exchange. In 2006, Miller was recipient of a NSF Discovery Corps Fellowship to catalyze and sustain U.S. and Brazil collaboration in chemistry of biomass conversions to biofuels. He has worked for university-based international programs, for a higher education association focused on principles of quality assurance for transnational educational offerings, and for a private voluntary organization dedicated to international allied health sciences. With a Ph.D. from the University of Arizona (and research interests and experience in scientific, professional, and academic mobility), a master's degree from the University of Northern Colorado, and a baccalaureate degree from the University of Virginia—Wise, Miller speaks French, Spanish, and Portuguese and has published nine articles and book chapters.

Mariko Ogawa is the executive advisor to the president, director of the Support Office for Women Researchers, and professor of history of science and science studies, Mie University,

Japan. Ogawa's teaching and research interests are in the history of biology and medicine in 19th century England and Germany, and in gender in science. She is the author of *Uneasy Bedfellows*, *Bulletin on History of Medicine* (2000), *The Mysterious Mr. Collins*, *Journal of History of Biology* (2001), *Robert Koch's 74 Days in Japan* (2003), *Liebig and the Royal Agricultural Society Meeting at Bristol, 1842* (2008), *Feminism and Technology/Science* (2001, in Japanese), and *Darwin Redux: Narrative in Evolutionary Theory* (2003, in Japanese). Recently, she has been engaged in several co-authored works and has translated many books into Japanese, especially those relating to gender in science. With her translations, four excellent books by Professor Londa Schiebinger, former director of the Clayman Institute, Stanford University, are now available in Japanese.

Willie Pearson, Jr., is professor of sociology, School of History, Technology, and Society, Georgia Institute of Technology. In 1993, he received Southern Illinois University's College of Liberal Arts Alumni Achievement Award. He specializes in the sociology of science and sociology of the family. He is the author or coeditor of six books and monographs and numerous articles and chapters. His most recent book is titled *Beyond Small Numbers: Voices of African American Ph.D. Chemists* (2005). Pearson has held research grants from NSF, National Endowment for the Humanities, Sloan Foundation, and U.S. Department of Justice. He has held postdoctoral fellowships at the Educational Testing Service and the Office of Technology Assessment, U.S. Congress. He is a fellow of AAAS, and has served as a lecturer in Sigma Xi's Distinguished Lectureship Program. He has served as chair of the Committee on Equal Opportunities in Science and Engineering, NSF, and as chair of the Committee for Science, Engineering and Public Policy, AAAS. In 2001, he was designated a lifetime national associate of the National Academies. Currently, he serves on advisory committees in the Education and Human Resources Directorate (NSF), the Burroughs Wellcome Fund, and NAS. His Ph.D. is from Southern Illinois University in Carbondale (1981).

Angelica Salvi Del Pero is a policy analyst at the Organization for Economic Cooperation and Development (OECD), where she is the administrator of the OECD Gender Initiative, which aims at identifying the main barriers to gender equality in education, employment, and entrepreneurship in OECD countries and other regions and assessing the experience with policies to address these barriers. Before joining the OECD in July 2010, Salvi Del Pero was a research fellow at Centro Studi Luca d'Agliano, an Italian think tank, and a consultant for the World Bank. She also held a postdoctoral position at the University of Pavia. She has worked extensively on poverty and income distribution in developing countries, as well as on firm performance and investment climate issues. Salvi Del Pero has taught various economics courses at the University of Milan. Salvi Del Pero holds a Ph.D. in economics from the University of Milan, an M.S. in economics from the University of Wisconsin–Madison, and a B.A. in business and economics from the University of Turin.

Johanna (Anneke) M.H. Levelt Sengers is a native of The Netherlands where she obtained her Ph.D. in physics in 1958. She immigrated to the United States in 1963 and made her career at the National Institute of Standards and Technology. Her expertise is in the area of thermodynamics and critical phenomena in fluids, with application to industrial fluids. In particular, she worked in an international context on standards for the properties of water and steam on behalf of the electric power industry. She is the 2003 L'Oréal-UNESCO for Women in Science Laureate for North America. Within the framework of InterAcademies Panel (IAP), the Global Network of Academies of Sciences, she was the coauthor of the InterAcademy Council Advisory Report *Women for Science*, which was adopted by IAP in 2006. She is currently the

chair of the Women for Science Working Group of the InterAmerican Network of Academies of Sciences (IANAS). She is a member of NAS and NAE.

Carol F. Stoel is a program director in Division of Graduate Education, Education and Human Resources Directorate at NSF. Her program responsibilities at NSF include Ethics Education in Science and Engineering, Integrative Graduate Education and Research Traineeship Program, and Science Master's Program.

Patricia Taboada-Serrano is the early-career representative in the Women for Science Working Group of the IANAS. She received her Ph.D. in environmental engineering from Georgia Institute of Technology in 2005. She was a postdoctoral research associate at the Oak Ridge National Laboratory from 2006 to 2008. From 2008 to 2010, she served as an adjunct professor in Bolivian Catholic University.

APPENDIX C

List of Participants

(Affiliations listed were those at the time of the workshop.)

Alice Abreu

Regional Coordinator
Rio+20 Initiative
The International Council for Science, and
Professor Emeritus
Federal University of Rio de Janeiro

Sybrina Atwaters

Graduate Research Assistant
School of History, Technology and Society
Georgia Institute of Technology

Kathie Bailey-Mathae

Director
Board on International Scientific Organizations
The National Academies

Lisa Borello

Ph.D. Candidate
School of History, Technology and Society
Georgia Institute of Technology

Janet Bryant

Scientist/Engineer IV
National Security Directorate
Pacific Northwest National Laboratory

Stefanie Bumpus

Science and Technology Policy Fellow
American Association for the Advancement of
Science
U.S. Department of Defense

Daryl Chubin

Director
Center for Advancing Science and
Engineering Capacity
American Association for the Advancement of
Science

Joanne Cohoon

Associate Professor
Science, Technology and Society Department
School of Engineering and Applied Science
University of Virginia

Keith Crank

Assistant Director
Research and Graduate Education
American Statistical Association

Ingrid Daubechies

Professor
Mathematics Department
Duke University, and
President
International Mathematical Union

Catherine Didion

Director
Committee on Women in Science, Engineering and
Medicine
The National Academies

Jessie DeAro

Program Director
Alliances for Graduate Education and the
Professoriate
Education and Human Resources Directorate
National Science Foundation

Kaye Husbands Fealing

Committee on National Statistics
The National Academies

Allan Fisher

Vice President
Laureate Education Inc.

Judy Franz

Executive Officer Emeritus
American Physical Society, and
Past Secretary General
International Union of Pure and Applied Physics

Lisa M. Frehill

Senior Program Officer
Committee on Women in Science, Engineering and
Medicine
The National Academies

Yolanda George

Deputy Director
Education and Human Resources Program
American Association for the Advancement of
Science

Joan Goldberg

Executive Director
The American Society for Cell Biology

Kellie Green

Christine Mirzayan Science and Technology Policy
Graduate Fellow
National Academy of Engineering

Wendy Hansen

Senior Researcher
Maastricht Economic and Social Research Institute
on Innovation and Technology
United Nations University

Katherine Hoffman

Membership Specialist
American Chemical Society

Sharon H. Hrynkow

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APPENDIX D

Data on Women Researchers in Science (Workshop Handout)

TABLE D-1. Women Researchers, As a Percentage of Total Researchers (head count)
2001-2008

Country	2001	2002	2003	2004	2005	2006	2007	2008
Austria	..	20.7	..	23.6	..	25.3	26.4	..
Belgium	..	27.7	28.1	28.8	29.6	30.7	31.1	..
Czech Republic	28.8	29.5	28.3	28.5	28.8	28.5	28.3	28.5
Denmark	28.0	26.2	28.1	..	29.7	..	30.2	..
Finland	29.1	29.9	29.8	29.0	30.2	31.6	31.5	30.7
France	27.5	27.8	27.8	27.8	28.0	27.4	..	..
Germany	..	..	19.5	..	21.4	..	23.2	..
Greece	35.3	..	37.1	..	36.4	..	..	..
Hungary	33.0	33.7	35.1	34.5	34.2	33.5	33.5	33.0
Iceland	34.7	..	39.4	..	39.3	38.6	37.8	37.8
Ireland	..	30.2	30.2	30.0	30.3	31.2	32.0 (p)	..
Italy	28.1	28.7	29.3	29.9	32.4	33.3	33.2	..
Japan	10.7	11.2	11.6	11.9	11.9	12.4	13.0	13.0
Korea	11.1	11.6	11.4	12.0	12.9	13.1	14.9	15.6
Luxembourg	..	..	17.4 (c)	..	18.2	..	24.1 (c)	..
Mexico	..	..	31.6 (c)	..	..	..	..	..
Netherlands	..	..	17.2	..	18.0 (c)	..	23.0	..
New Zealand	39.3	..	..	..	..	..	..	..
Norway	28.3	..	29.4	..	31.7	..	33.3	33.9
Poland	..	..	39.3	38.9	39.3	39.5	39.9	39.5
Portugal	43.6	44.0 (c)	44.3	44.4 (c)	44.4	43.8 (c)	43.4	..
Slovak Republic	..	39.6	40.6	41.2	41.5	41.8	42.3	42.3
Slovenia	35.36	35.09	32.20	32.52	34.79	35.28	34.88	35.08
Spain	35.4	35.2	36.3	36.1	36.7	36.7	37.0	..
Sweden	..	..	..	..	35.8	..	34.5	..
Switzerland	..	..	..	26.7	..	..	..	30.2
Turkey	35.2	35.6	35.9	36.4	36.1	36.3	36.7	..
United Kingdom	..	..	..	..	35.7 (c)	..	36.6 (c)	..

NOTE: The notation (c) indicates that this is a national estimate or projection adjusted if necessary by the Secretariat to meet Organization for Economic Cooperation and Development (OECD), norms and (p) indicates that this is provisional data.

SOURCE: Organization for Economic Cooperation and Development, Main Science and Technology Indicators, Science, Technology and R&D Statistics, 2010.

TABLE D-2. Women Researchers by Sector of Employment, As a Percentage of Total Researchers, 2008

Country	Business Enterprises	Government	Higher Education	Private non-Profit
Argentina	2.55	13.62	33.38	0.90
Portugal	4.33	8.39	26.54	5.11
Romania	10.85	9.70	22.54	0.18
Russian Federation	22.87	16.19	3.04	0.06
Slovak Republic	4.03	6.71	30.99	0.01
South Africa	5.60	2.67	31.17	0.28
Iceland	12.14	11.67	14.21	1.25
New Zealand	1.89	1.97	27.54	7.87
Poland	3.09	5.81	30.30	0.05
Spain	6.47	7.26	22.86	0.11
Greece	5.33	3.56	27.27	0.21
Turkey	3.67	1.78	30.82	0.00
Sweden	12.97	2.15	20.46	0.16
Slovenia	8.28	10.45	16.56	0.07
Hungary	5.12	7.22	21.13	0.00
Italy	5.09	5.97	19.37	1.92
Norway	7.89	4.59	19.25	0.00
Mexico	5.99	4.83	19.02	1.72
Finland	9.10	4.59	17.32	0.54
Ireland	8.38	1.10	20.76	0.06
Denmark	13.92	2.60	12.86	0.32
Belgium	8.75	1.62	19.36	-0.16
Czech Republic	5.20	8.20	14.99	0.08
France	9.03	3.60	14.51	0.70
Singapore	14.02	2.22	10.85	0.00
Switzerland	6.80	0.65	19.37	-0.08
Austria	5.87	1.90	15.50	0.35
Germany	5.27	3.11	12.99	0.00
Chinese Taipei	8.02	2.79	9.47	0.18
Luxembourg	10.60	5.40	2.21	0.00
Netherlands	5.90	4.61	7.20	0.31
Korea	7.01	0.77	5.08	0.27
Japan	4.11	0.55	7.61	0.14

SOURCE: Organization for Economic Cooperation and Development, Main Science and Technology Indicators Database, April 2008.

TABLE D-3. Employed Female Scientists and Engineers in the United States, by Occupations, Highest Degree Level, As a Percentage of Total Scientists and Engineers, 2006

Occupation	All Degrees		Bachelor's		Master's		Doctorate	
	Both sexes	Female (percent)	Both sexes	Female (percent)	Both sexes	Female (percent)	Both sexes	Female (percent)
All occupations	18,927,000	44	10,886,000	45	5,384,000	47	883,000	30
S&E occupations	5,024,000	26	2,911,000	24	1,497,000	29	566,000	28
Scientist	3,403,000	33	1,865,000	31	1,023,000	37	467,000	33
Biological/life scientist	487,000	44	203,000	51	113,000	47	154,000	34
Agricultural/food scientist	57,000	32	32,000	38	15,000	27	10,000	20
Biological/medical scientist	336,000	49	137,000	59	76,000	55	107,000	36
Forestry and conservation scientist	35,000	14	22,000	14	11,000	9	2,000	N/A
Postsecondary teacher	60,000	40	13,000	54	11,000	55	34,000	29
Computer and Information Scientist	1,963,000	26	1,350,000	25	557,000	26	50,000	16
Computer/information scientist	1,938,000	25	1,345,000	25	546,000	27	41,000	15
Postsecondary teacher	25,000	32	5,000	20	11,000	45	9,000	22
Mathematical Scientist	149,000	39	44,000	41	70,000	43	33,000	27
Mathematical scientist	85,000	38	32,000	41	39,000	41	12,000	25
Postsecondary teacher	64,000	39	12,000	42	31,000	48	21,000	24
Physical Scientist	334,000	28	159,000	33	84,000	32	89,000	17
Chemist, except biochemist	134,000	35	79,000	39	26,000	42	28,000	18
Earth scientist / geologist / oceanographer	80,000	20	39,000	21	30,000	20	11,000	18
Physicist/astronomer	29,000	14	6,000	17	7,000	14	16,000	13
Other physical scientist	39,000	31	25,000	32	10,000	30	3,000	33
Postsecondary teacher	52,000	29	9,000	44	11,000	45	31,000	19
Psychologist	211,000	65	22,000	73	98,000	69	76,000	55
Social scientist	259,000	46	86,000	51	102,000	44	66,000	39

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System.

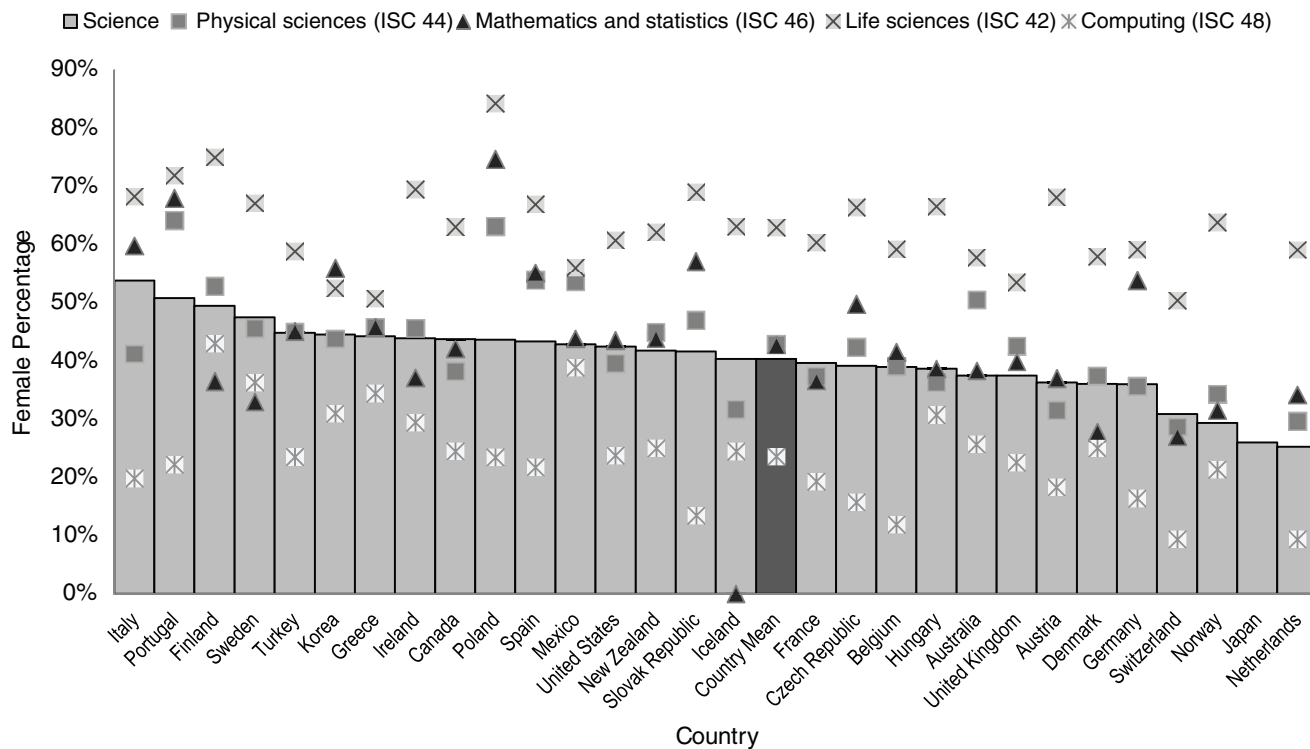


FIGURE D-1. Percentage of Women Graduates¹ by Field of Study, 2005

SOURCE: Organization for Economic Cooperation and Development Education Database, 2011. Figure created by Wei Jing.

¹ Graduates from tertiary type A and advanced research programs.

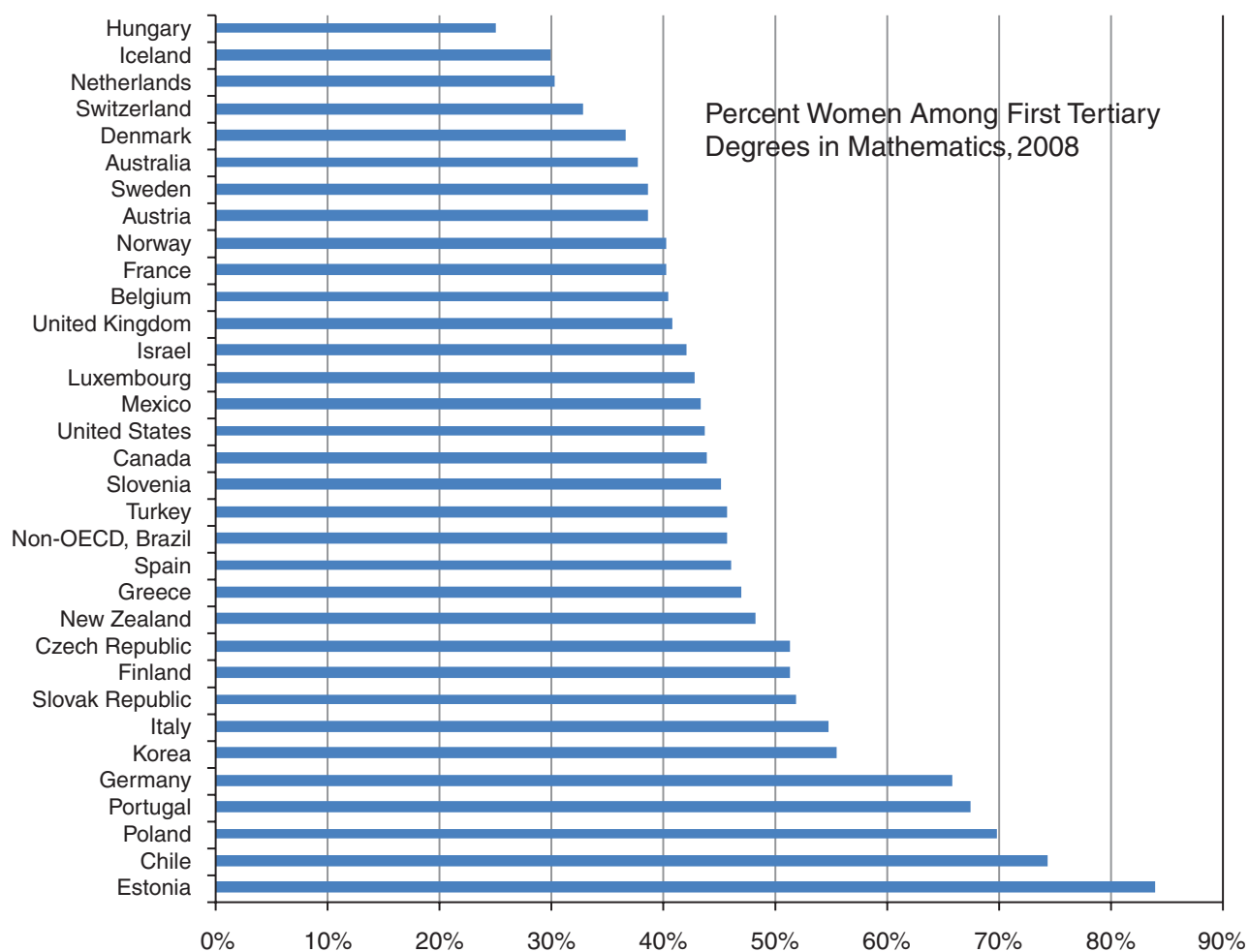


FIGURE D-2. Percentage of Women Among First Tertiary Degrees in Mathematics, 2008

SOURCE: Organization for Economic Cooperation and Development, StatExtracts, 2011. Figure created by Lisa M. Frehill.

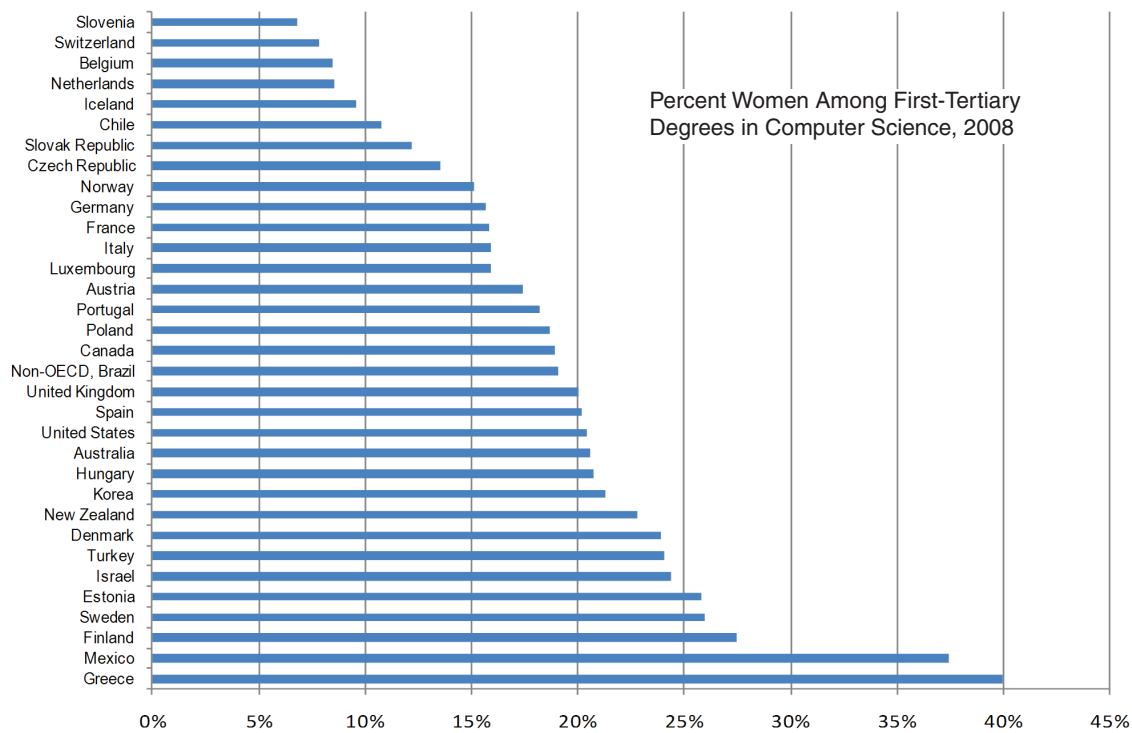


FIGURE D-3. Women’s Representation in Computing Varies Across Countries

SOURCE: Organization for Economic Cooperation and Development StatExtracts, 2011. Figure created by Lisa M. Frehill and J. McGrath Cohoon.

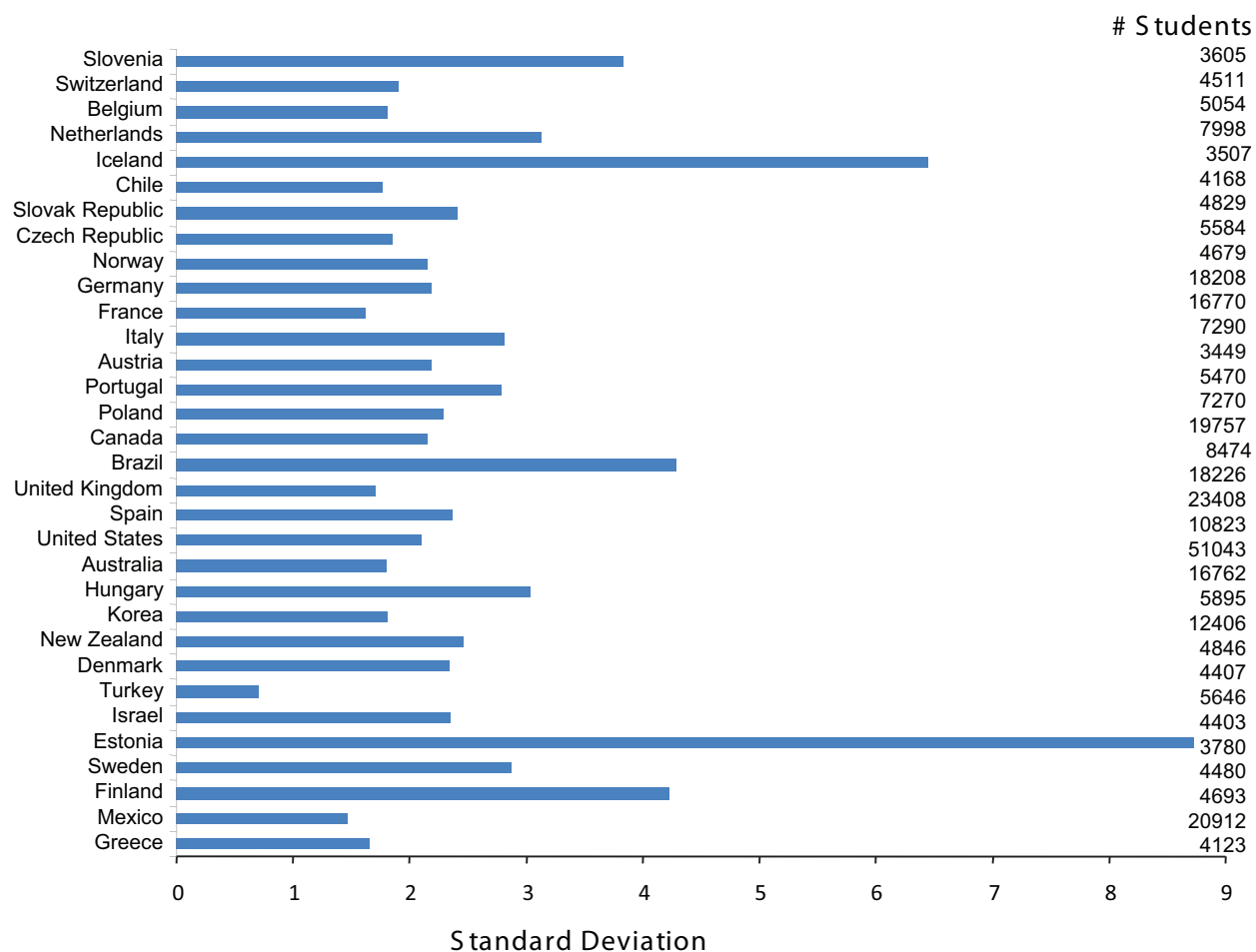


FIGURE D-4. Women’s Share of Tertiary Computing Degrees as Deviation Below Mean Discipline, 2006-2007

SOURCE: Organization for Economic Cooperation and Development, StatExtracts, 2011. Calculations and figure created by J. McGrath Cohoon, Sergey Nigai, and Rachna Maheshwari.

APPENDIX E-1

A Snapshot of Gender Differences in Education¹

*Angelica Salvi Del Pero*²

Education is essential to advancing human capital by enabling individuals to develop their knowledge and skills throughout their lives. Relatively high levels of education are often related to higher earnings and productivity, better career progression, health, life satisfaction as well as to better investments in education and health of future generations.

Figure E-1-1 presents five key indicators (in four panels) for Organization for Economic Cooperation and Development (OECD) and selected emerging economies to illustrate “gender gaps” in participation, attainment, performance in education, as well as field of study. The gender gaps are defined as the difference in scores of men and women relative to the male score for indicators where men have the highest scores on average (i.e., Program for International Student Assessment [PISA] maths scores and the proportion of degrees awarded in mathematics and computer sciences), and the difference in scores between women and men relative to female scores when female scores are highest on average (i.e., enrollment in secondary education, proportion of adults with tertiary education and PISA reading scores). For example, Figure E-1-1, panels A and B show that in Australia, compared with boys, girls on average have a 5 percent disadvantage in secondary education enrollment, a 23 percent advantage in proportion of young adults with tertiary education, and a 7 percent advantage in PISA reading scores (i.e., secondary school enrollment of boys is 105 percent of that of girls, the proportion of young men attaining tertiary education is 77 percent of that of younger women, and PISA scores for boys is 93 percent of that of girls). Similarly, panels C and D of Figure E-1-1 show that Australian boys have a 2 percent advantage in PISA maths scores and a 72 percent advantage in the proportion of mathematics and computer science degrees awarded, compared with girls (i.e., girls’ PISA math scores are 98 percent of that of boys’, and the proportion of mathematics of computer science degrees awarded to women is 28 percent of the proportion awarded to men).

Gender gaps in participation levels can be gauged by looking at secondary gross enrollment rates (Figure E-1-1, Panel A). Among OECD countries there are no substantial gender gaps in secondary enrollment rates (mostly within 5 percent) except for Turkey, where women have a strong disadvantage. On the other hand, tertiary attainment levels are higher for girls than for boys in most OECD countries (Figure E-1-1, Panel A), and in Finland, Portugal and Slovenia, young women are much more likely to participate in tertiary education than young men (i.e., a gender gap larger than 40 percent). Only in Mexico, Switzerland, and Turkey is the

¹ Abstract from *Report on the Gender Initiative: Gender Equality in Education, Employment and Entrepreneurship Meeting of the Organization for Economic Cooperation and Development (OECD) Council at Ministerial Level—Paris, 25-26 May 2011*.

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share of adults with tertiary education significantly higher among men than women (i.e., a gender gap smaller than -10 percent), and in Chile there is only a very slight advantage of men over women (gender gap -1 percent).

The remaining three panels of Figure E-1-1 show that in OECD countries the main gender differences in education relate to performance and preferences across field of study. Gender differences in cognitive skills among adolescents are shown in Figure E-1-1, Panel B and C. At age 15, girls outperform boys in reading in all countries; boys, on the other hand, perform better than girls in mathematics in most countries but there are a few countries (Finland, Indonesia, the Russian Federation, Slovenia, and Sweden) where the gender gap is small (less than 5%). In terms of science, there are no substantial differences in performance.

The largest gender differences, on average, are observed in the chosen field of study in tertiary education (Figure E-1-1, Panel D). The positive gap in the proportion of degrees awarded in mathematics and computer science implies that, in all OECD countries, men account for the majority of degrees awarded in these subjects; women in turn account for the vast majority of graduates in the arts and humanities. Differences in the gender composition of graduates in mathematics and computer sciences are large in all countries but they are particularly pronounced (i.e., above 80 percent) in Belgium, Iceland, the Netherlands, Slovenia, and Switzerland. Furthermore, gender gaps in the proportion of tertiary degrees awarded in mathematics and computer sciences are much larger than the gender gaps in performance at age 15 in performance in mathematics (respectively 64 percent and 2 percent on average in the OECD).

A full assessment of gender inequality in education for emerging economies according to the selected indicators is only possible in Brazil, but information is available for most indicators for Indonesia and the Russian Federation. There is little gender inequality in participation in secondary education in Indonesia and the Russian Federation while there are large gaps in Brazil to the advantage of girls (10 percent) and in India to the advantage of boys (-14 percent). Tertiary education attainment rates of young women exceed those of men in the Russian Federation and in Brazil, with gender gaps of 20 percent and 29 percent, respectively.

In emerging economies, the performance of boys and girls in the different subjects at the secondary level mirrors the trends observed in most OECD countries: in Brazil, Indonesia, and the Russian Federation girls do significantly better in reading while boys score marginally better in mathematics. In Brazil, as in OECD countries, considerably more young men than women choose mathematics and computer science courses (gender gap of 71 percent), while the opposite is true in Indonesia.³

While educational outcomes vary across and within countries, there is no one country that consistently has large gender gaps (with an advantage to either men or women) or a near gender parity across all indicators.⁴ Across the OECD, even for countries such as Austria, Chile, Germany, Korea, and United Kingdom, where the gender gap is less than 10 percent in absolute

³ The reasons behind the inversed gap in Indonesia will have to be explored further: While these United Nations Educational, Scientific, and Cultural Organization data are slightly different than the data for most countries in the table, insofar as they do not include postgraduate degrees, this inconsistency is not likely to explain the gap reversal.

⁴ These gender gaps as well as the levels for boys and girls are presented in the Annex to Chapter 1 in “Report on the Gender Initiative: Gender Equality in Education, Employment and Entrepreneurship Meeting of the OECD Council at Ministerial Level—Paris, 25-26 May 2011,” where they are compared to the OECD average to categorized countries in “above” or “below” groups if they are at least half a standard deviation above or below the OECD average.

value for four of the five indicators, the gap in degrees awarded in mathematics and computer science is still high.

On the whole, gender gaps in educational outcomes differ between advanced economies and developing countries. In the former, girls perform better than boys, whereas they lag behind in the latter. In advanced economies, coming from a disadvantaged socio-economic background has a larger negative effect for male students while in developing countries the negative effect is larger for girls.

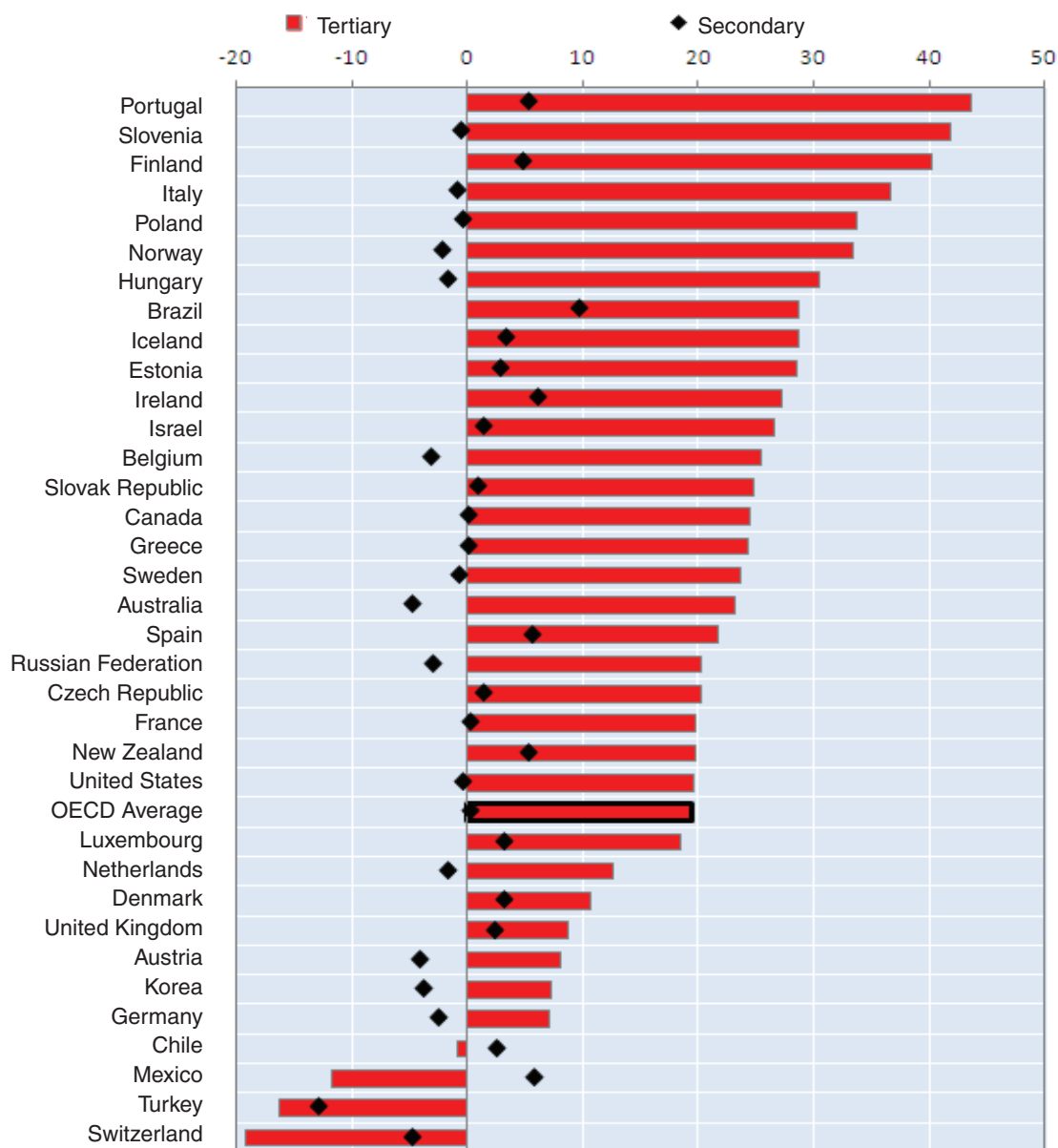


FIGURE E-1-1. Panel A. Secondary Enrollment Rate and Tertiary Attainment — Male Gap to Female (in Percentages)

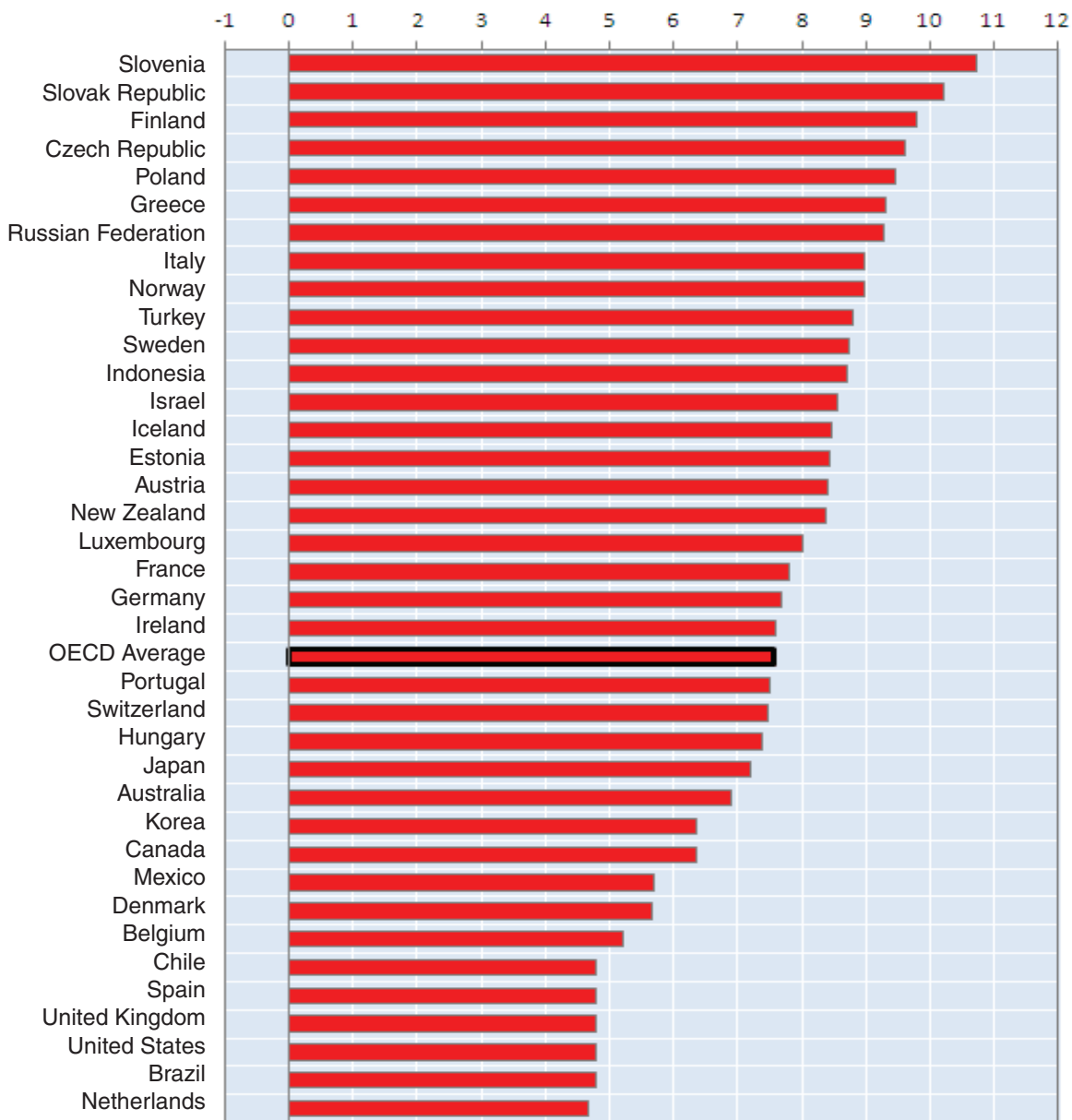


FIGURE E-1-1. Panel B. PISA Reading Scores—Male Gap to Female (in percentages)

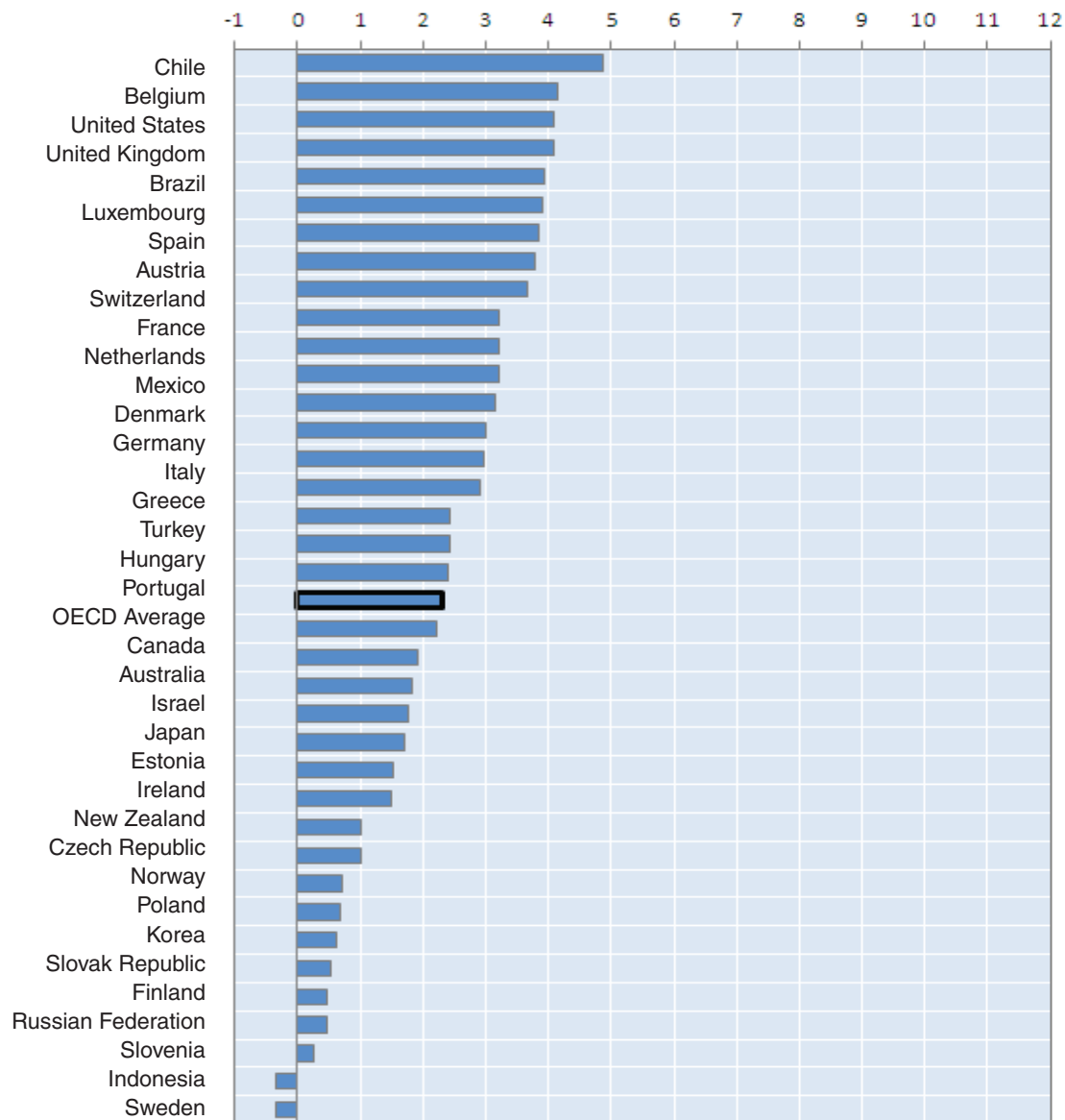


FIGURE E-1-1. Panel C. PISA Mathematics Scores—Female Gap to Male (in percentages)

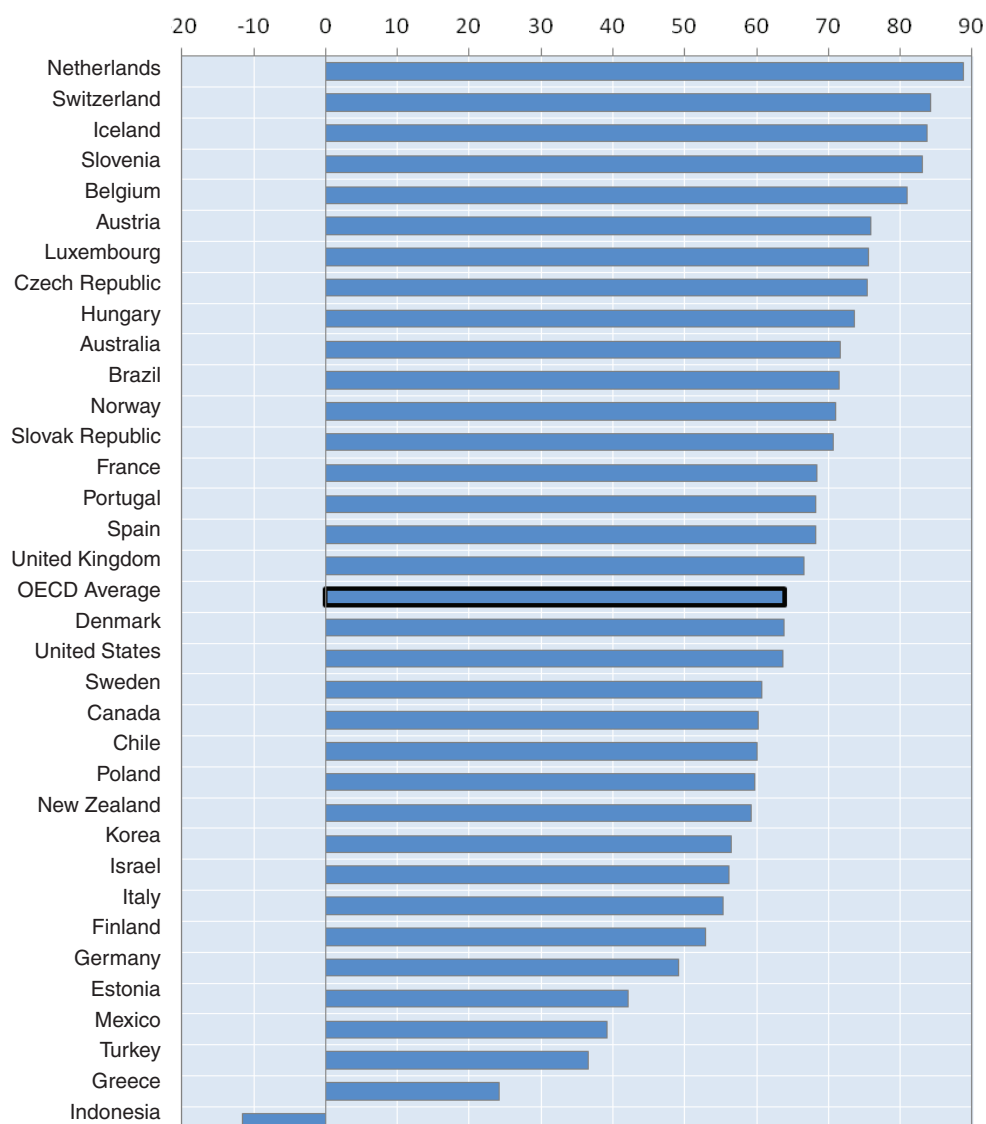


FIGURE E-1-1. Panel D. Degrees Awarded in Mathematics and Computer Science—Female Gap to Male (in percentages)

NOTE: Male to female gaps are defined as $(\text{female}-\text{male})/\text{female}$; female to male gaps are defined as $(\text{male}-\text{female})/\text{male}$.

SOURCE: Table A1.1, in the Annex to Chapter 1 in “Report on the Gender Initiative: Gender Equality in Education, Employment and Entrepreneurship Meeting of the OECD Council at Ministerial Level—Paris, 25-26 May 2011.”

APPENDIX E-2

Historical Perspectives on Women in Chemistry, Computer Science, and Mathematics

Mariko Ogawa,¹ Lisa M. Frehill,² Sophia Huyer³

Chemistry has a long history ultimately dating back to alchemy, although there have not been as many female chemists in history as female mathematicians. Maria Sklodowska Curie (1867-1934) and her daughter, Irène Joliot-Curie (1897-1956) won Nobel Prizes in Chemistry in 1911 and in 1935. Over the past several centuries, chemistry has been able to attract women to undergraduate study. Indeed, the Women's Committee of the American Chemical Society in the United States was founded 85 years ago.

Crystallography is an exceptional field related to chemistry. In England, in the first half of the 20th century, the research groups of both William Henry Bragg (1862-1942) and his son William Lawrence Bragg (1890-1971), who were 1915 Nobel laureates in physics, attracted remarkable numbers of female researchers. Kathleen Yardley Lonsdale (1903-1971), Dorothy Mary Crowfoot Hodgkin (1910-1994), and Rosalind Elsie Franklin (1920-1958) were the most distinguished three women in the Braggs research tradition. Lonsdale was elected as the first female member of the Royal Society in 1945. Hodgkin was a Nobel Prize winner in chemistry in 1964. Franklin has recently become known for her crucial contribution to the identification of the double-helical structure of DNA. The Braggs' record of employing women chemists illustrates that environment and encouragement are important in women's participation (Julian 1990).

However, the capital-intensive nature of laboratory work in chemistry has posed special challenges for women's participation. Without access to equipment, supplies and space, performing chemistry experiments can be problematic. So if academic institutions and chemical industry employers do not hire women—such as was the case prior to World War I and again after the immediacy of war needs no longer prevailed—then women who are trained in chemistry in college have fewer options to practice in the field. Instead, they seek work in which the science background is useful but for which laboratory resources are not required. Henry Etzkowitz's recent idea of a "Vanish Box," whereby highly trained women disappeared from academic bench science and subsequently reappeared in technology transfer offices at the interface between science and economy, is an example of this process (Etzkowitz 2009).

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The nature of work in mathematics, however, differs compared to chemistry. That is, mathematics work involves few resources, often merely a paper and pencil. Indeed, in the 18th and 19th centuries, women enjoyed solving mathematical problems as a contest. The *Ladies Diary* was designed specifically for the amusement and entertainment of women with an appendix of curious and valuable mathematics papers for use by students (Perl 1979; Costa 2000; Costa 2002).

There were many women who were good at mathematics in their student lives. One excellent example was Philipa Fawcett (1868-1948), who was ranked above the Senior Wrangler in 1890, achieving the highest mark in mathematics at the University of Cambridge. While there were other female Wranglers, no other ranked as senior or as second. Grace Chisholm Young (1868-1944), who marked almost equivalent to a Senior Wrangler in 1892, received her Ph.D., magna cum laude, from Göttingen in 1895.

However, seven examples in the history of famous women mathematicians are traditionally noted. Their accomplishments prove that women could be highly skilled mathematicians⁴ (Osen 1974; Alic 1986). These exemplars include

- Hypatia (about A.D. 360-A.D. 415)
- Maria Gaetana Agnesi (1718-1799)
- Émilie du Châtelet (1706-1749), who translated into French, with commentary, Isaac Newton's work *Principia Mathematica*
- Sophie Germain (1776-1831), French mathematician
- Mary Somerville (1780-1872), Scottish popular science writer; her talent was highly appreciated though she lacked scientific originality
- Sofia Vasilyevna Kovalskaia (1850-1891), Russian mathematician, professor at University of Stockholm
- Emmy Noether (1882-1891)

The presence of such notable women contradicts the common myth that women are not good at mathematics. The “math myth” however, has proved rather intractable even today. Witness, for example, the world's most popular doll, Barbie, and her Japanese sister, Licca.⁵ Both dolls have issues with mathematics. Licca is poor at mathematics, but good at art and music. And when Barbie finally spoke in 1992, one of the first phrases programmed in for her 800 million young owners to hear was “math class is tough” (Schiebinger 1999). So that, despite the low resource requirements necessary to perform mathematical work, persistent gendered stereotypes have thwarted women's participation in the field in some cultures.

Computer science is a much newer discipline. However, some of the foundations for the discipline were established by two notable women. The name of Grace (Brewster Murray) Hopper (1906-1992) should be designated foremost among early computer scientists. She worked for the U.S. Navy and was engaged in the development of the first BINAC and later UNIVAC. She was mainly involved in designing software for digital computers. The development which made her name famous was the computer language COBOL. She was the most famous female computer science specialist of the 20th century. But we also find her

⁴ Osen and Alic are two of the seven world famous female mathematicians; sometimes Caroline Herschel (1750-1848) was added.

⁵ For more information about the Japanese doll Licca, see *Licca chan hausu no hakurankai* (Exhibition of Licca's House) (in Japanese, Tokyo: INAX, 1997), p. 5.

forerunner in the 19th century. Mathematician, Augusta Ada Byron, Countess Lovelace (1815-1852) was the first developer of conceptual programming for Charles Babbage's Analytical Engine. The Ada programming language in the Pentagon is named after her.

In summation, then, when we look at women's participation in the chemical sciences, mathematics, and computer science, we are able to point to some notable women in each field, yet women's pursuit of these fields as a profession has been affected by larger social forces. In mathematics, women had access to the field as a recreation and to study mathematics at universities in England. The chemical sciences' resource-intensive nature of work stood as a barrier to women's participation. When employers had labor shortages, such as during the First World War, women chemists were able to locate work. But when they were no longer needed, women were pushed out of the laboratory. Finally, some elements of computer science are like mathematics with a lower need for expensive resources, so it is a field that could have been able to attract women who could have been inspired by the achievements of women like Grace Hopper and Ada Byron.

So far, our emphasis has been on notable women in chemistry, computer science, and mathematics in the developed world, specifically, Europe and North America. When we turn our attention to developing a history of these fields and women's participation in the developing world, there are many challenges. Much literature is from Western Europe and North America therefore there is a need to engage with multilingual literature for broader global coverage. Furthermore, science is in the early stages of development in many developing countries, therefore information can be difficult to locate. In addition, the colonial past and path to independence hold many implications for women's participation in science. There is a body of work about women's participation in agriculture that was impacted by colonial processes and that, now, has provided a backdrop against which women become involved in science. Finally, the chemical industry, which is capital-intensive, has also been rather mobile in the 20th century. Hence, as the capital resources for the chemical sciences move to new locations, new labor forces must be developed. In such cases, there is a need to consider the interaction of gender within contexts.

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APPENDIX E-3

Institutional and Cultural Parameters Affecting Women's Participation in the Fields of Chemistry, Mathematics, Statistics, and Computer Science around the World

*Anne J. MacLachlan*¹

How women enter higher education, attain degrees, and work in chemistry, mathematics, statistics, and computer science is essentially regulated by the different cultures within their national societies. These express social, economic, and political values about the role of women in society, and shape the values of academic institutions. The latter are sometimes contradictory and burdened with a historical legacy inimical to the full participation of women in science. At the same time, an increasing international consensus about the practice of science tends to be much more supportive of women training and working in these fields.

What follows is a brief analysis of the multiple cultural and institutional factors affecting women's participation in science and mathematics around the world. Increasingly the major international institution for participation in science is the research university. Its origins are mixed, but the most emulated form developed in the United States after World War II. That this form flourished there is an accident of history. In 1945, few other countries were able to pour national resources into higher education after economies, infrastructure, and millions of citizens were destroyed by the war. The development of research universities was a deliberate result of federal policy and in tandem with the increase of national and private laboratories. After 1957, when the Soviets launched Sputnik, federal funds poured into universities, expanding facilities for big science, and increasing the number of doctoral-granting programs and graduate students (Geiger 2009). Undergraduate enrollment expanded from 1,494,203 in 1940 to 16,386,738 in 2008 (Chronicle of Higher Education [CHE] 1974; CHE Almanac, 2010). The research university or a similar form has a monopoly on doctoral conferral, and a historical legacy of exclusivity, internal stratification, and competition among academic fields. It transmits both academic and social values to students and sustains them in successive generations of scientists.

For modern research universities to successfully sustain their functions and the growing participation of women there are several preconditions. Historically, the most significant is the accumulation of wealth within a society sufficient for the development and support of cultural and educational institutions. The universities of Paris and Bologna, the better known European antecedents of the modern university, originated during the middle ages when the development of trade and production created sufficient wealth able to support centers of learning. Initially organized by the Roman Catholic Church to train priests, these universities later trained men for

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the professions of law and medicine. Although legally independent, universities existed by charter conferred by the monarch, and were valuable in staffing royal administration and developing the modern state. In many respects, early European universities had much in common with religious schools and academies in the Moslem and Asian worlds. In later centuries, however, the latter parted ways with how science and technology developed and the gradual democratization of access to secondary education in the West (Perkins 1991). A second precondition for the modern research university, therefore, is a well-functioning primary and secondary educational system to prepare students for university education. Intrinsicly, this system of education should be largely secular and supportive of national and international norms of scientific inquiry and with a political system upholding both.

Closely associated with the creation of the modern research university is the growth of disciplinary and professional associations. Although not directly a precondition, they contribute to the organization of knowledge in a form in which standards of research are sustained and central concepts of each field are transmitted along with a discrete set of behaviors that set boundaries among the different fields. The fields and their professions are defined by the German sociologist Stichweh as “forms of social institutionalization... of processes of cognitive differentiation in science” (Stichweh 1994). As Tony Becher has put it so well in his *Academic Tribes and Territories*, this results in the creation of a scientific community with mutually comprehensible communications and a subject-specific language which defines the group and separates it from other knowledge-based groups (2004). This enables the growth of theoretical knowledge represented in textbooks characterized by: a.) codification, acceptance by consent, teachability; b.) a set of research methods and paradigmatic problem solutions; c.) a discipline-specific career pattern; d.) institutionalized socialization processes which serve to select and educate candidates according to the prevailing paradigms (Stichweh 1994).

Disciplinary membership became part of an international culture, which, as it developed, established that science is something men do, not women. While this is changing—and in some countries, changing rapidly—disciplinary organizations support the cultural framework for informal male networks, which continue to exclude women from access to higher education and professional employment.

By itself, the research university is a highly differentiated environment both apart from and reproducing the norms of society at large (Marginson 2010; Jaschik 2011). Today in the West, its values still bear traces of the period when the very small number of academics in universities were an elite, separated from the rest of society by the nature of intellectual work, who were curators of esoteric knowledge and recognized as members of an independent legal entity. Social and economic privileges accompanied this unique legal status, e.g., the two votes of each professor in German national elections until the Nazi period. One should remember that in any society prior to the modern period, academics were usually priests, thought to have a special relationship with god; indeed one can think of modern examples in which senior male professors tend to confuse themselves with god.

Along with a special status, the university and its faculty carry a particular responsibility as public actors. In the pre-modern period, this included preserving and transmitting knowledge and serving as expert advisors in largely illiterate societies. Today, this role is far more visible as academics advance knowledge through research and transmit it through teaching, publication, and service as experts, faintly echoing their historic role. All of these aspects of the present research university impinge on the participation of women in chemistry, mathematics, statistics, and computer science. Women are newcomers to a historically developed community, not yet

necessarily members of the elite club. Their presence in universities brings conflicts among different values: the role of women in society, disciplinary expectations, and those of the university.

Documenting how these cultural and institutional values affect women's participation today in the various regions of the world and in a limited number of countries illustrative of regional trends follows a uniform analysis. The first part of the analysis is historical, examining how the structure of the Western university developed together with science and technology. Second, it charts the role of Western science in imperial domination of the non-European world, and how universities were created in some parts of the world as instruments of political and ideological control (Vlahakis 2006).

For example, the conquest of what is now Latin America and the Caribbean by Spain and Portugal led to the Jesuits' creation of educational institutions in the early 1500s. These educated local elites promulgated Christian thought and Luso-Hispanic world views to the detriment of indigenous knowledge. Today much elementary and secondary schooling is still run by the Jesuits and other Christian orders. Universities no longer follow the imperial model, but inescapably reflect an inherited cultural system largely unsupportive of independent roles for women (Europa Publications 2010). While increasing numbers of universities are becoming modern research universities, scientific research facilities lag and the entire region only produces 2.5 percent of the world's doctoral scientists (Koiller 2007). As part of this discussion, attention is paid to when chemistry, mathematics, statistics, and computer science developed as modern university subjects.

This example suggests how historical legacies affect the current situation, including the number and types of higher education institutions and the number and percentage of college age cohort enrollment. This is significant in order to understand why women in many countries are far less than half of tertiary enrollment. For example, India only enrolls 10 percent of this cohort, so it is not so surprising that women proportionately are underrepresented at Indian universities (Altbach 2010). This low percentage is offset by the size of India's overall population and its over hundred-year-old tradition of training doctoral scientists at European and American universities.

Following this is an exclusive focus on women in which girls' participation in secondary education and the extent to which science and mathematics are included in the curriculum. This has a direct bearing on when and in what numbers women were admitted to degree programs in chemistry, mathematics, statistics, and very recently, computer science. Most of this discussion is about the 20th and 21st centuries. Women's attainment of advanced degrees and subsequent professional employment also reflects the extent of their participation in the disciplinary associations.

The goal of this analysis is to illuminate the current situation of women in the four fields and lay the groundwork for later detailed analysis.

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APPENDIX E-4

Workforce Sex Segregation

Alice Abreu,¹ Lisa M. Frehill,² Kathrin K. Zippel³

Our work focuses on the concepts and measurement tools of workforce segregation at the macro, middle, and micro levels of analysis. At the macro level, we consider the labor-force at the national or institutional level. The middle level of analysis pushes us to attend to how the institutional processes of qualification, training, recruitment and retention within scientific careers are impacted by the social institution of gender. Finally, at the micro level, we grapple with the ongoing debates around the concept of “choice.” That is, to what extent do differences in occupational structures and careers reflect choices made by active agents, and to what extent are choices constrained by gender as a social institution? How do individuals navigate through scientific careers within these larger contexts?

Macro Level

At the macro level, the observed differences in the distributions of women and men into different occupations reflect the outcomes of a wide range of social forces, operating at the macro, middle, and micro levels, some of which may have intentionally sought to disadvantage women, while others result in different treatment of women and men, patterned by gender, as unintended consequences. As such, segregation is simply a description of an existing set of relations. The intentionality of the social forces that lead to segregation are a matter of much debate, to which we are encouraged to consider once we engage in the comparative analyses associated with the metrics.

To what extent is workforce segregation an intentional outcome? This is a critical issue. In the United States, the English word “segregation” often calls forth images of residential segregation that, in U.S. history was, indeed, intentional and enforced by both law and custom. Such an issue may not be present in discourse about workforce segregation in other countries where the term does not carry this historical “baggage.” The point is still salient, though, regardless of context. In some contexts, women’s work and men’s work are, or have been, explicitly segregated. Again, while this may be accomplished by force of law, informal customs and practices should not be overlooked; even in advanced industrial nations, jobs like nursing are seen as “women’s work” and jobs like engineer are seen as “men’s work.” At the other end of the spectrum, though, segregation may be viewed as an unintended consequence of individuals’ choices.

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Segregation can be described along both horizontal and vertical dimensions. The horizontal dimension describes how women and men are distributed across some set of occupational fields or, in the case of educational programs, different fields of study. Figure E-4-1, for example, shows the subfields of women and men who earned doctoral degrees awarded by mathematics departments in the United States in 2008. The largest number of degrees was awarded in statistics and biostatistics, in which women accounted for 51 percent of the Ph.D. recipients. Women also accounted for just more than half (54 percent) of the doctoral degrees in mathematics education. Among the other nine fields shown in the chart, women accounted for between 12 percent (probability) and 31 percent (differential, integral, and difference equations) of the doctoral degree recipients.

The vertical dimension, then, provides an understanding of segregation within a system that involves ranking. Vertical segregation looks at a particular occupation, or set of occupations, to see how people from different social groups occupy different levels within that occupation. Figure E-4-2, using data from the U.S. National Science Foundation, shows the distribution of women and men across the ranks of U.S. doctoral-degree mathematics faculty. Typically, faculty in the full and associate professor ranks also hold tenure, while those in the assistant and instructor/lecturer ranks are not tenured. Each rank represents a level of additional advancement over the previous one. While women are split nearly equally in the two senior ranks and the two junior ranks, more than half of male doctoral-degreed mathematics faculty were full professors. Altogether, about 80 percent of men faculty in mathematics held relatively secure and powerful positions, while women were more likely to be in lower-level positions. Further, one-in-ten women mathematics faculty holding doctoral degrees were in what are often considered the least secure and least powerful positions as instructors/lecturers.

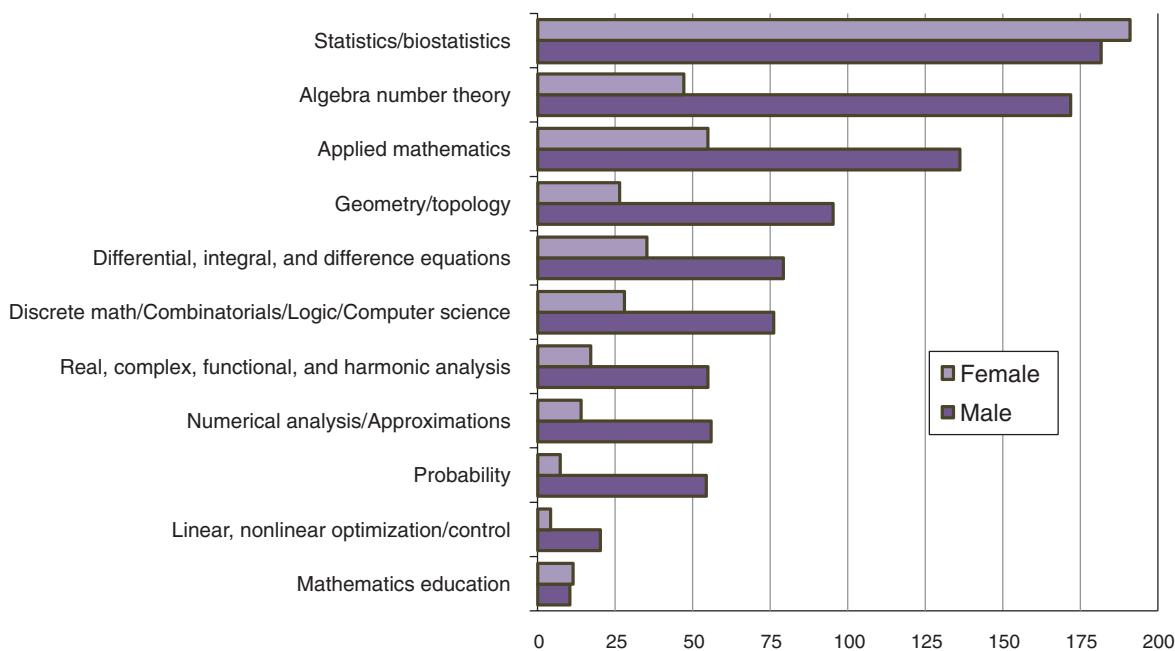


FIGURE E-4-1. Horizontal Segregation: Representation in Mathematics Subfields by Sex of Doctoral Degree Recipients, 2007-2008

SOURCE: Authors' Analysis of data in Phipps, P., J.W. Maxwell, and C.A. Rose. 2009. 2008 Annual Survey of the Mathematical Sciences in the United States. *Notices of the AMS* 56(7):828-843.

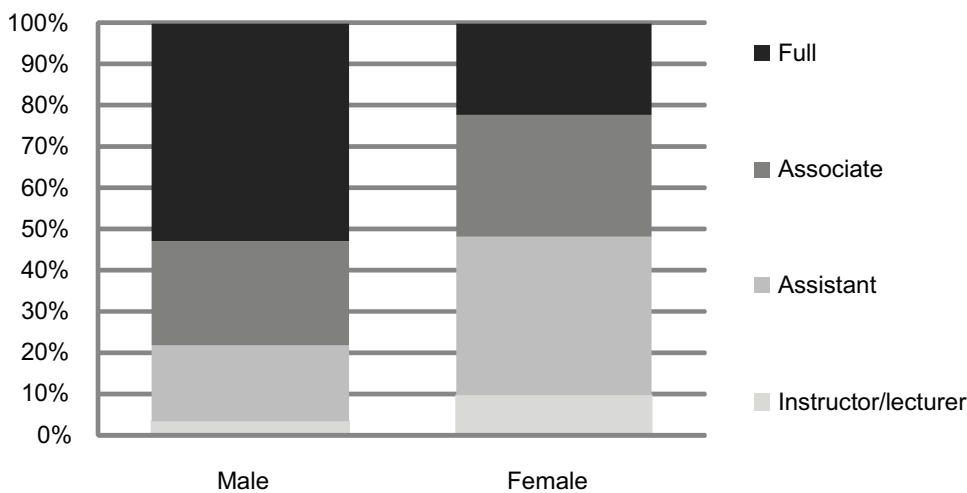


FIGURE E-4-2. Vertical Segregation: Faculty in Mathematics by Sex and Rank of U.S. Doctoral Degrees in Mathematics, 2006

SOURCE: Authors' Analysis of Data in NSF. 2009. *Characteristics of Doctoral Scientists and Engineers in the United States, 2006, Detailed Statistical Tables* NSF09-317.

Metrics associated with both of these dimensions have been developed and well-articulated in the literature. Some metrics were originally developed by demographers to measure residential segregation. Over time, these measures have been subsequently refined to measure differences between groups in their placement in occupations or fields of study. These metrics, which are typically normalized in an appropriate way, permit analysis across different contexts (national, institutional—i.e., university level, different fields or disciplines) and across time. Later work will develop and apply these metrics to occupational segregation in computer science, mathematics and statistics, and the chemical sciences in greater detail.

Middle Level

What explains the horizontal and vertical segregation shown at the macro level? What are the underlying causes of the gender segregation? How do these factors differ at various stages and levels of a scientific career? Middle level analyses focus on the processes and institutional contexts in which new workers are recruited, trained and attain qualifications and advancement. How is gender a factor in these processes? Who makes the decisions within institutions, and to what extent are these decision-makers provided with information with which to judge potential workers? What are the biases in the information that is provided or in the processes associated with these judgments?

It becomes clear that complex processes are at work and that a gendered perspective is essential to understanding what has been metaphorically called the “leaking pipeline,” “the crystal labyrinth” and “the glass ceiling syndromes.” Examining processes within institutional contexts, such as workplaces and schools, will allow us to discuss some of these factors.

Terms like “leaking pipeline,” “the crystal labyrinth,” and “the glass ceiling,” all refer to the processes by which workers enter and move through jobs in organizations. The “leaking pipeline” metaphor is often used in contexts that suggest that individuals’ choices are often viewed as the source of the leakage. The terms “crystal labyrinth” and “glass ceiling,” however, are not completely value-neutral, embodying the notion that the processes by which women are segregated into lower level or less powerful positions operate like the invisible hand in the market, and that these processes that produce outcomes, such as those shown in Figure E-4-2, are not visible.

The term “work-family balance” has entered the lexicon to understand the lower participation levels of women in various areas of science and for different rates of advancement of women and men in those areas in which women may already have achieved parity at the entry level. When the former is used, the word “family” invokes images of gendered domesticity that connect the concern with this balance to women. Recently, in recognition that there are various non-work issues that need to be balanced with work, the term “work-life balance” is becoming more popular. Regardless of the term, this issue is raised as a common explanation for women’s lack of advancement in science fields as due to women’s greater connection to family, necessitating trade-offs of career advancement and family balance.

Why are men more likely than women to be in higher-level faculty positions, as shown in Figure E-4-2? Metaphors like “the glass ceiling” or the “crystal labyrinth” suggest that perhaps the institutional processes of advancement in higher education settings are not visible to women but they are to men. Invoking explanations using terms like “work-family balance,” however, suggest that perhaps women are more likely than men to choose to attend to family matters to the detriment of their careers.

Figure E-4-3 shows horizontal segregation of women among doctoral degree recipients in Brazil in 1996 and 2008. If metaphors like the “leaky pipeline” are invoked, then why are there such broad variations across fields in women’s participation? That is, why is women’s representation in some STEM fields so low, while women have a higher level of representation in other fields? Why are these gender differences more pronounced in the United States and other affluent countries than in transitional and developing countries? As shown in Figure E-4-3, one third of doctoral degrees in engineering were awarded to women in Brazil in 2008, while in that same year in the United States, just 20 percent of doctoral degrees in engineering were earned by women.

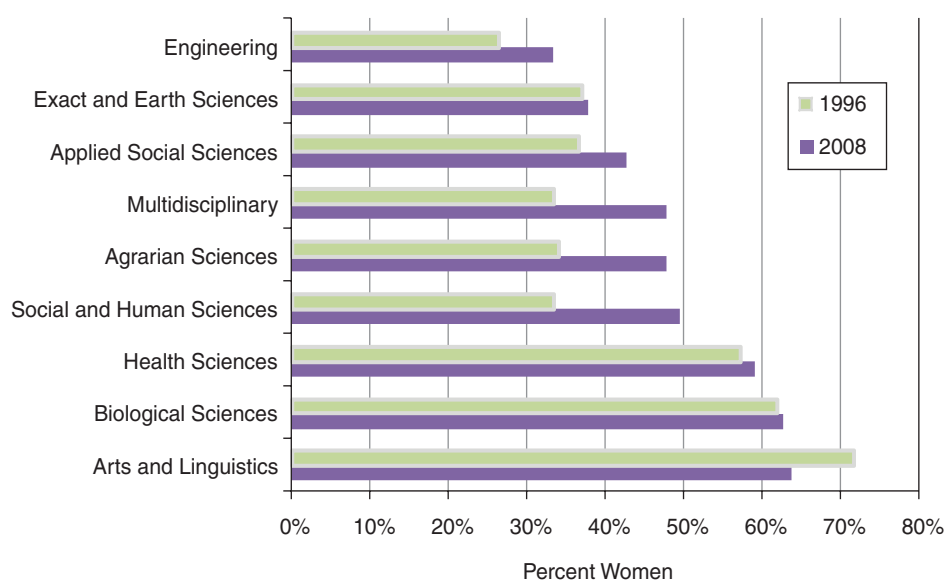


FIGURE E-4-3. Women’s Representation among Ph.D. Recipients in Brazil by Field, 1996 and 2008

SOURCE: Doutores Estudos da demografia da base técnico-científica brasileira - Brasília, DF: Centro de Gestão e Estudos Estratégicos, 2010.

Micro Level

At the micro level, we shift our focus closer to the individual level in relation to the institutional level processes just considered at the middle level. At this level we are particularly interested in the calculus of choice. Here we reach what can often be a slippery slope: while we can conceptualize individuals as active agents of their own lives, the extent to which individuals are effectively channeled into some areas or blocked out of others can represent significant constraints on these choices. To what extent do the choices about careers and curriculum of individuals continue to be made along gender lines? To what extent do actors possess accurate

and full information about these fields? What are the situations in which individuals find themselves and how do these situations impact the choices that they make related to fields of study and careers?

For example, return for a moment to the issue of “work-family balance.” Women and men face the same question: How do I balance the needs of my family with those of my employer and/or my career? But the decision about this balancing act is made within a particular social context and then within a particular household situation. The choice made by the household about, say, care of minor children is influenced by many factors including: the presence of affordable, high-quality daycare; employers’ willingness to permit workers to leave earlier in the afternoon to attend to children; the relative income provided by each member in the couple; and social norms related to gender and the care of children.

SUMMARY

This paper provides a framework within which to understand segregation processes at three levels: macro, middle and micro. Measurement tools at the macro level in this chapter provide metrics with which to make comparisons of segregation in computer science, mathematics and statistics and the chemical sciences across work contexts (e.g., industry, government, and academia), across nations/economies, and across time. Theories at the intersection of social organizations and the social construction of gender reveal how institutional processes, at the middle level, play a role in occupational segregation. Finally, at the micro level, individuals’ interactions and choices, as well as the constraints and meanings of those choices, can be analyzed to understand the gendered outcomes associated with decisions about education and work.

APPENDIX E-5

Status of Women in the Chemical Sciences

Robert Lichter,¹ Willie Pearson, Jr.,² Lisa J. Borello,³ Janet L. Bryant⁴

Introduction

The world of academia is a very tough one, with real funding problems. Particularly as a woman, this really puts me off it. As well as the long hours required, necessity to travel to conferences regularly as group leader, the battle for funding would not go well with hopes to have children one day.

The comment above comes from a woman respondent to a survey of chemistry doctoral students published in 2008. Although the more than 650 responses revealed considerable concern by both men and women about their futures as researchers in the chemical sciences, women expressed more reservations than men. For example, the proportion of women Ph.D. students planning a science-related career fell from 85 percent in the first year to 79 percent in the third year, while the proportion of men *increased* from 73 to 86 percent in the same period. More strikingly, the proportion of women who planned a career as a research chemist fell from 72 percent in the first year to 37 percent in the third, while the proportion of men remained about the same (61 to 59 percent). Of those women who were planning a research career, 51 percent intended during their first year of graduate study to stay in academia, but this proportion fell to 33 percent in the third year. The drop in men's interest was smaller: 44 to 36 percent from the first to the third year. Overall, only about 12 percent of women planned to remain in academia compared to 21 percent of men.

Focus groups and interviews with participants in the survey established some of the reasons for these findings. These included inadequate or sometimes hostile supervision, a sense of isolation and exclusion, various implied messages that questioned their competence, and the "macho" environment for doing research. For an academic career, women perceived that the potential rewards were insufficient incentives to overcome the challenges and compromises required for success, and that an industrial setting would provide a more compatible environment. Those challenges and compromises included the all-consuming and insufficiently collaborative requirements for success, challenges to building of family and other relationships, and advice from others that they were likely to be less competitive by virtue of their gender.

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Such perceptions are not uncommon among women at this career stage in the United States. However, this examination took place not in the United States but in the United Kingdom.^{5,6} That the perceptions in that country so closely echo those that have emerged from similar studies in the United States raises the question, of course, of how general these outcomes are across a wide swath of countries and cultures. This critical question is what underlies the ongoing effort to collect data about the status of women chemists across a range of countries.

WHY CHEMISTRY?

Although recent years have witnessed measurable gains by women in receiving first and advanced university degrees in the chemical sciences,⁷ the progress of women chemists through their careers, as in most other science and engineering fields, continues to lag behind those of men worldwide.⁸ Gender disparities persist in pay, promotion rates, and access to certain areas of specialization, and women are often excluded or underrepresented in research and in key leadership positions. The consequence is the inability to have the largest pool of people from whom to draw the top talent required to address global economic and societal challenges, and to sustain a country's global economic competitiveness. In the United States, increased competition from Germany, Italy, Japan, Spain, the United Kingdom, and South American and Asian countries—all of which have been making more strategic investments in chemistry research and education—poses a growing concern for policy-makers.

While increasing the participation of and leadership by women in all STEM⁹ fields is vital, it is especially critical in the chemical sciences for two important reasons. First, the fundamentals of the chemical sciences underpin advances in many other scientific and technical arenas: biology, materials, electronics, environmental sciences, and more. Second, chemical scientists work in a variety of settings, mostly non-academic, not just in those specific to their disciplines. Thus, in addition to recruitment, *retention* of talented women in the chemical sciences and advancement to positions of leadership across employment sectors is of equal importance. Notwithstanding recent gains, women are lost at each rung along the career ladder, with many highly trained women opting out of careers in chemistry altogether.

Data Collection Challenges

Owing largely to data limitations across the globe, much has remained unknown about the status of women chemical scientists on a global level, in educational attainment, and particularly regarding career outcomes. This is a serious challenge. Understanding the reasons for women's slow progress, and developing effective policies and programs to advance women in the chemical disciplines, both require robust and reliable data that can be compared across

⁵ S. Dickinson and J. L. Newsome. 2008. *Change of Heart: Career Intentions and the Chemistry Ph.D.* Royal Society of Chemistry.

⁶ J. L. Newsome. 2008. *The Chemistry Ph.D. The Impact on Women's Retention.* Royal Society of Chemistry and the United Kingdom Resource Center for Women in SET. Available at <http://www.rsc.org/ScienceAndTechnology/Policy/Documents/WomenRetention.asp>.

⁷ Hansen, D.J. 2010. Gains Continue for Chemistry Grads. *Chemical Engineering News*. 88(34):44-54.

⁸ National Science Board. 2010. *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation (NSB 10-01). Available at <http://www.nsf.gov/statistics/seind10/>.

⁹ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

countries and cultures. Doing so can reveal common factors that can facilitate shared solutions across national boundaries, and uncover factors unique to a national or cultural setting that may require unique approaches.

Four major hurdles to collecting the required data emerged during the course of this project. First is the absence of much data altogether. Many countries simply do not collect data on the status of women scientists at all, or do so in only a limited way. Second, where data are available, they are often not disaggregated into individual disciplines but are combined, for example, into general areas such as physical sciences or biological sciences. Third, where data for individual disciplines are collected, they are often not comparable across national borders because of the disparate nature, degree of completeness, assignment of responsibility, and methodological inconsistency of data collection across regions. No sole entity has taken the lead for gathering and analyzing global data on education and labor market trends, not only in the chemical sciences, but also for STEM fields in general.

Fourth, no consensus on an operational definition of a chemist exists beyond the notion that “a chemist is what a chemist does.” For many, “chemical sciences” generally includes chemistry and closely related sciences that are grounded in fundamental chemical principles. These may include, for example, biochemistry, materials sciences, biophysical chemistry, chemical biology, and some areas of nanosciences. In some cases, these fields are considered separately; in others, they may be classified into chemistry, biology, physics, or even some engineering fields. These differences make cross-national comparisons difficult. Furthermore, because chemists work in a variety of venues, most of which are outside the more-easily counted academic settings, surveys can often overlook them.

Example

Nonetheless, within these constraints, meaningful data can still be extracted that allow some cross-cultural comparisons. Sources of data include journal publications, government reports and statistics, reports compiled from professional organizations and technical societies, and personal inquiries to contacts in other countries. The National Science Board’s *Science and Engineering Indicators* is a particularly rich source of limited global information available.

An example of the desired kinds of comparisons is given in Table E-5-1. Trends over a number of years (not given here) demonstrate that the percentage of women receiving first and third degrees in chemistry has been increasing steadily. Table E-5-1 shows the percentage of women receiving first (bachelors) and third (doctorate) degrees in three Western countries: Germany, the United Kingdom, and the United States. Table E-5-1 also compares these numbers with the percentage of women on chemistry doctoral faculties in the same countries. The close tracking of the percentage of degrees awarded to women among the three countries, and the comparable drop in the percentage of women faculty members, suggest the existence of common factors that require further examination.

TABLE E-5-1. Percent of First and Doctorate University Degrees in Chemistry Awarded to Women, and Percent of Women on Academic Chemistry Faculties in Doctoral Institutions, 2008

Country	First degree	Doctorate	Faculty
United States	50	39	16*
United Kingdom	50	40	12
Germany	40	38	11

* Data for 2009, doctoral institutions only.

SOURCES: Schmitz, K. 2009. Hochschullehrnachwuchs und Professorinnen. 2008. *Nachrichten Chemie*. 57:463-465 (April), and "Who is Teaching Whom?" *Complete Report on the Fall 2009 Committee on Professional Training Survey of Faculty Status*. *American Chemical Society*. Fall 2010. Available at http://portal.acs.org/portal/PublicWebSite/about/governance/committees/training/reports/cptreports/CNBP_025912.

Steps Toward Change

The slow pace of change in the status of women chemists does not imply that no attempts have been made to effect positive change. In the United States and elsewhere, a variety of governmental and private efforts, not outlined here, have been in place for some years. Since 1994, the United Kingdom's Royal Society has offered Dorothy Hodgkin Fellowships annually to early-career scientists who do not yet hold permanent positions and who require flexibility in their working patterns because of personal matters such as childbirth and parenting, family care responsibilities, or health issues.¹⁰ The intent is to keep promising younger scientists, especially women, engaged in science on a part-time basis even while they attend to such personal issues. Stipends are relatively generous and include funds for research-related activities, and the term can last up to four years. Regrettably, only ten of these are awarded each year across a number of scientific disciplines, so the systemic impact is obviously limited. In Germany, both the chemical industry and the unions representing their workers have jointly created a number of programs for advancing women chemists in industry, and for addressing work-life balance issues.¹¹

¹⁰ The Dorothy Hodgkin Fellowship program page is available at: <http://royalsociety.org/grants/schemes/dorothy-hodgkin>.

¹¹ National Chemistry Employers Association (BAVC) and the Mining, Chemistry, and Energy Workers Union (IG BCE), "Chancengleichheit im Betrieb: Umsetzung und Erfahrungen,[online]." Report of a 1999 Conference on Women in German industry, Progressdruck, Speyer, Germany, August 2000. Available: <http://www.cssa-wiesbaden.de/fileadmin/Dokumente/chancengleichheit.pdf>, accessed 12/22/2011; and Wolfgang Goos and Veronika Keller-Lauscher, "Chancengleichheit in der Chemischen Industrie,[online]" Buchdruckwerkstätten Hannover GmbH, Hannover, Germany, January 2002. Available: http://www.bavc.de/bavc/web/web.nsf/id/pa_publ_chancengleichheit.html. [Accessed 12/22/2011].

Next Steps

The examples presented here are intended to give a flavor of the data and comparisons sought in the ongoing project, and underscore the need for broader-based data collection and examination. Even if relevant data turn out not to be generally available, the questions that arise are expected to propel the necessary efforts to generate those data, and thus shape policies and programs internationally that can advance women, and make their influence more visible, in the chemical sciences.

APPENDIX E-6

Computer Science: Cross-National Snapshots of Entry Degrees and IT Workforce in Selected Countries

J. McGrath Cohoon,¹ Caroline Simard,² Juliet Webster,³ Cecilia Castano,⁴ Juliana Salles,⁵ Jane Prey,⁶ and Jacques Wainer⁷

The discipline of computer science studies the principles, designs, applications, and impact of computers and problem-solving processes. Professional-level occupations in this field include jobs such as systems analysts, network systems and data communications analysts, and computer and information scientists. Computing professionals work in every industry, from health to entertainment, and they tend to be well-paid compared to other occupations.

This intellectually engaging discipline and its creative and rewarding occupations exhibit substantial and increasing gender imbalance in most, but not all, countries around the world. This essay illustrates cross-national variation in computing's gender composition with snapshots of women's representation at the typical educational entry point and in the workforce.

Gender Composition of Degrees in Computing Varied Across Countries

Women's share of tertiary computing degrees varied across countries in 2008, as evident in Figure E-6-1, which graphs data from the Organization for Economic Cooperation and Development (OECD). These numbers are somewhat misleading, however, because they fail to account for context.

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⁴ Cecilia Castano, professor in Applied Economics, Complutense University Madrid.

⁵ Juliana Salles, program manager, External Research and Programs, Microsoft Research.

⁶ Jane Prey, senior research program manager, Microsoft Research Connections, Microsoft Research.

⁷ Jacques Wainer, associate professor in computer science, the Instituto de Computação da UNICAMP, Brazil.

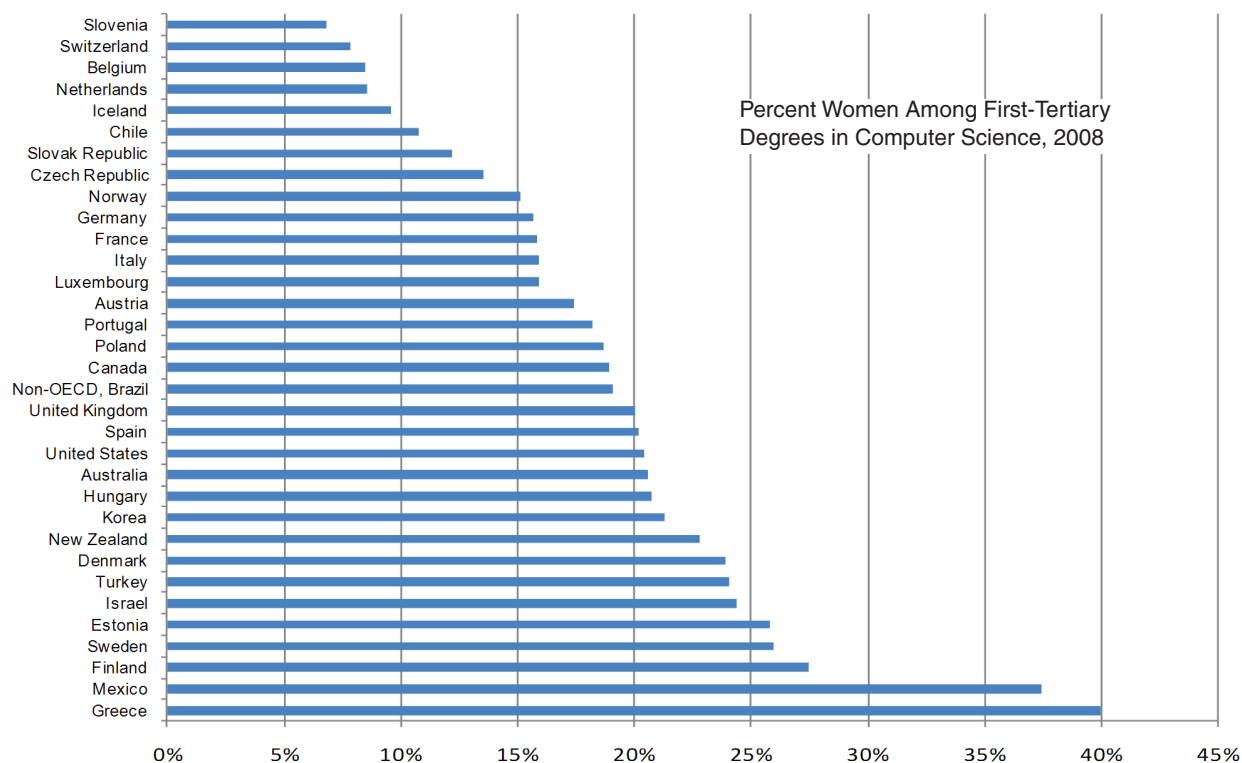


FIGURE E-6-1. Women's Share of Computing Degrees

SOURCE: Organization for Economic Cooperation and Development (OECD) Education Database.

To put computing into context, one must recognize that women's participation in higher education also varied from country to country. In many nations, women were quite well-represented, often exceeding men's level of participation in higher education. In countries such as Korea and Turkey, however, there were only 65 to 75 women for every 100 men earning a college degree (39 percent to 43 percent). Likewise in India, which was not included among the OECD countries listed, women were underrepresented at a comparable percent. They comprised 41 percent of the 2007 total enrollment in Indian higher education.⁸ In contrast, countries such as Brazil, Spain, and the United States reported overrepresentation of women in their higher education institutions. In Spain, women were 55 percent of undergraduates; in Brazil they were 56 percent; and in the U.S., they were 58 percent.⁹

This country-level contextual information is crucial if we wish to avoid confounding gender balance in tertiary computing programs with issues of women's access to higher education. To account for in-country educational conditions, we averaged women's share of degrees for all disciplines in a country and calculated the standard deviation from that average

⁸ Calculated based on data retrieved from World Bank Country Data. Available at: <http://data.worldbank.org/country>

⁹ Calculated based on data retrieved from World Bank Country Data. Available at: <http://data.worldbank.org/country>

representation. Then we can measure the difference between women's representation in computing compared with their representation in the average discipline. Figure E-6-2 shows for the same countries as in Figure E-6-1, the extent to which women's representation in computing deviated below their representation in the country's mean discipline. The longer the bar, the more computer science in that country stands out as having unusually poor representation of women.

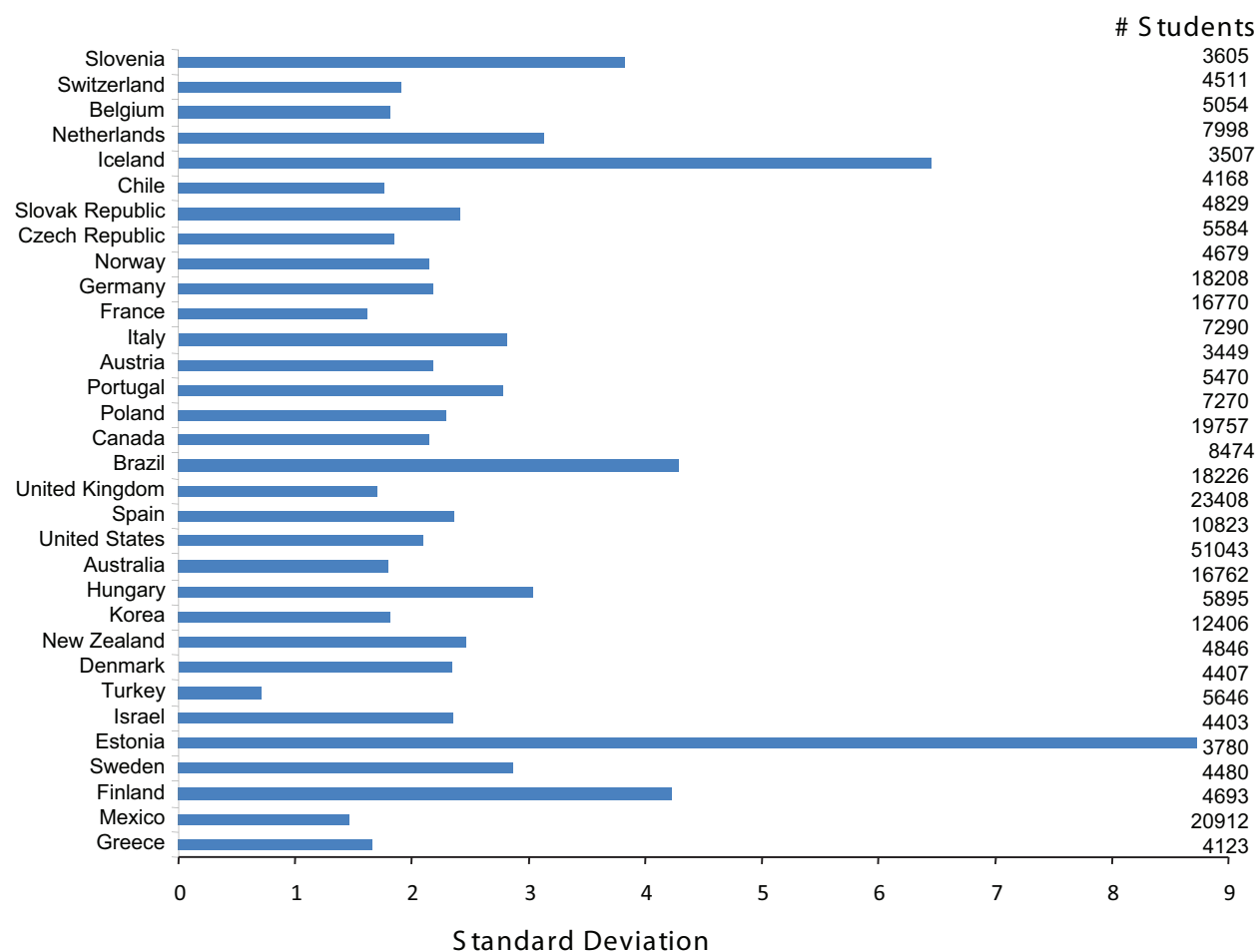


FIGURE E-6-2. Women's Representation Relative to Non-Computing Disciplines

SOURCE: OECD Education Database.

As evident in Figure E-6-2, computing was gender imbalanced to women's disadvantage in every one of these OECD countries. In most countries, women's share of tertiary computing degrees was exceptionally low. Only in Turkey was that imbalance less than one standard deviation below the mean, because 24 percent female was not so different from women's share of the average discipline in that country. Iceland, in contrast, exhibited particularly poor female representation in computing—9 percent—compared with the typically high level of Icelandic women in other disciplines. In Estonia, where women at first seem relatively well represented in computing (more than 25 percent, as shown in Figure E-6-1), the contextual information about

women's typical representation in other tertiary degree programs made clear that computing's gender balance was quite unusual. Virtually no other discipline in Estonian higher education exhibits this level of female underrepresentation.

In India (not shown), some engineering colleges now reserve 30 percent of enrollment for women (Mumbai Human Development Report 2009). Prior to implementation of these affirmative action policies, women were 26 percent of India's 2005 Engineering/Technology-B.E. Level courses (calculated with data from Selected Educational Statistics, Government of India, Ministry of Human Resource Development, Department of Higher Education, computing-specific data were not available). Compared with the OECD countries in Figure E-6-1, India exhibited one of the highest representations of women. Indian women's low participation in higher education (38 percent of all Bachelor degrees in 2005) also means that technical degrees were not exceptionally deviant; women's representation in technical fields like computing and engineering was just 12 points less than their overall representation.

The big picture is that women in every country investigated were underrepresented in computing, but the relative severity of their underrepresentation varied widely from country to country. A glance at the numbers of students graduated, listed at the right of Figure E-6-2, also makes clear that this variation was independent of computing's overall enrollment.

Gender Composition in the Computing Workforce Varied across Countries

Comparative data such as that presented for higher education are less available for the computing workforce. We therefore present information from four selected countries: Brazil, India, Spain, and the United States. It is not always possible to find the same type of data for the same year to represent all four countries. For context, the available data were women's employment numbers for the workforce overall and by occupational categories that include professional-level computing and other occupations.

The educational systems in the first three countries produce new entrants to the computing workforce who are about 20 percent women. India's computing graduates are about 26 percent women. It seems a reasonable assumption that women's representation in the computing workforce correlates with the supply produced by the educational system, although other factors such as trends and women's participation in the labor force probably also exert an influence.

Women's Workforce Participation Provides Context

As with education, countries vary in the extent to which women are in the workforce. In Brazil, 60 percent of women aged 15 and older were in the workforce in 2009 (World Bank). Brazilian women recently composed 42 percent of the overall workforce, held 43 percent of executive positions, and made up an even higher percent (67 percent) of professionals in the Arts and Sciences. Looking at just the "Professionals" sub-classification of the Brazilian workforce in 2007, women composed 59 percent (calculated with International Labor Force data). Based on these statistics, it seems that Brazilian women are well represented in occupations that call for a college education or better.

In Spain's workforce, women were less well-represented than in Brazil. Of all women aged 15 and older in 2009, only 49 percent were in the Spanish workforce. They composed 44 percent of the overall workforce in 2009 (European Commission [EC] 2010), and 34 percent of

business leadership positions in 2007 (EC 2009). Women in Spain were 54 percent of employed persons holding a Bachelors or Masters degree in 2009.¹⁰

In the United States, 58 percent of all women aged 15 and older were in the workforce in 2009. In the same year, women composed 47 percent of the entire U.S. workforce and 57 percent of the “Professional and related occupations.”¹¹ Although substantial horizontal segregation persists, many U.S. women participate at high levels in certain occupations.

In contrast, women’s representation in the overall Indian workforce was much lower than in the three Western countries we considered. Only 33 percent of women aged 15 and older were in the workforce in 2009.¹² (They composed 31 percent of the entire Indian workforce in 2008, and 32 percent of the “Professional, technical & related workers” in 2005.¹³ Another source puts women at 35 percent of the urban population holding “diploma/certificate” degrees in 2007 (National Sample Survey Organization 2009).

Women’s Participation in the Computing Workforce

Despite women’s high level of participation in many areas of Brazil’s, Spain’s, and the U.S.’s workforces, they comprised low and often declining shares of computing jobs that called for a college-level education. As shown in Figure E-6-3, Brazilian women comprised only 20 percent of the computing professional-level workforce. In Spain, women comprised 20 percent of computing professionals in 2009.¹⁴ In the U.S., women composed 24 percent of the computing workforce in 2009.¹⁵

In India, women’s level of participation in computing is disputed. Reports put women’s representation in the software industry at 36 percent women in 2008 (Nascom & Mercer 2009), but these numbers may include women not working in technical positions. A survey of software professionals in two large Bangalore tech firms found that women comprised 18 percent of those working as developers, module leaders, project leaders, or project managers in 2003 (Ilavarasan 2007). Because this finding is comparable to a previous industry report of women as 21 percent of the software workforce in 2001 (Noronha & D’Cruz 2006), it seems reasonable to estimate Indian women’s level of participation in professional level computing occupations at about 20 percent.

¹⁰ Calculated based on data retrieved from Instituto Nacional de Estadística 2010. Available: <http://www.ine.es>.

¹¹ Calculated based on data retrieved from Current Population Survey, Bureau of Labor Statistics, 2010.

¹² Calculated based on data retrieved from World Bank Country Data. Available at: <http://data.worldbank.org/country>.

¹³ Calculated based on data retrieved from International Labor Organization (ILO) Subregional Office for South Asia, 2010. Available: http://laborsta.ilo.org/MDTcountries_E.html.

¹⁴ Calculated based on data retrieved from European Union Labor Force Survey (EU LFS) 2010. Available: <http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/lfs>.

¹⁵ Calculated based on data retrieved from Current Population Survey, Bureau of Labor Statistics, 2009.

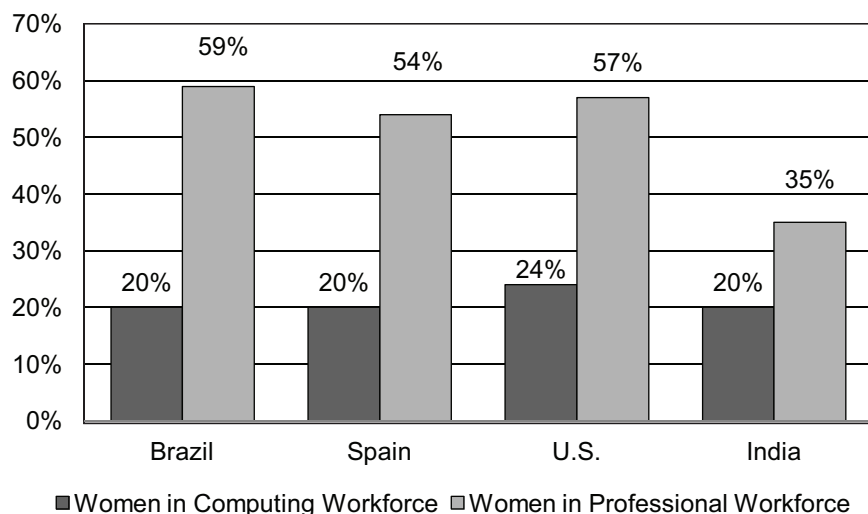


FIGURE E-6-3. Country Comparisons of Employed Women

SOURCES: Calculated based on data retrieved from European Union Labor Force Survey 2010, the current Population Survey, Bureau of Labor Statistics, 2009, and Nasscom & Mercer. 2009. *Gender Inclusivity in India: Building Empowered Organizations*. New Delhi, India.

Figure E-6-3 makes clear that among the selected countries, there was little variation in women's representation in the computing workforce. The range for each country in the latter half of the first decade in this century was 20 to 24 percent. This workforce representation may parallel women's share of computing degrees in each country. Another interesting observation is that, like the situation in higher education, Indian women are relatively better represented in computing in the context of their low participation in the professional workforce. India exhibits a 15 point gap between women in the professional workforce and women in computing, compared with a 39 point gap for Brazil, a 34 point gap for Spain, and a 33 point gap for the United States. So, while women are far from well-represented in Indian computing occupations, computing jobs do not stand out as especially deviant in the context of their workforce.

Possible Reasons for Cross-National Variation in the Gender Composition of Computing

Cultural beliefs about gender and about the nature of computing occupations can influence the gender composition of a field if social structures facilitate indulging those stereotypes. For that reason, women's participation in computing tends to be low in societies where computing is viewed as particularly suitable for men, where the culture and economic conditions encourage career choice as a form of self-expression, and where the educational system offers early opportunities for opting out of math and science (Charles and Bradley 2006). When choices are more constrained and careers are chosen pragmatically, there may be more women in computing. India may be an example of the latter circumstances—women's relative economic participation and opportunities are particularly low. India was ranked 127th out of 134 countries, while Brazil was 75th, Spain was 90th, and the United States was 17th (Hausmann, R., Tyson, L. Zahidi, S. 2009). Indian women have few other good options, so they are less likely to “indulge their gendered selves” (Charles and Bradley 2009).

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APPENDIX E-7

Disciplinary Societies' Role in Women's Status in Chemical Sciences, Computer Science, and Mathematics and Statistics

Lisa M. Frehill¹

Disciplinary associations are formal organizations that connect individuals or multiple entities that see themselves as holding a similar occupational background. In this précis, we use the term “disciplinary associations” rather than professional societies because in some cultures, the term “professional society” connotes a specific normative framework, i.e., performing state functions of licensing or other certification of members. In the North American context, however, the terms are interchangeable.

The foundations for this work come from social theorists who were interested in understanding the emergence of new social networks as a consequence of large-scale societal changes. Georg Simmel, in his essay “The Web of Group Affiliations” argued that increasingly, society could best be viewed as the result of a complex set of relationships in which individuals were connected to each other via shared memberships in formal organizations. Max Weber’s classic “Class, Status and Party,” argues that organizations that represent occupational groupings would come to be important political actors in an increasingly bureaucratic society. Emile Durkheim’s approach encourages us to examine the ways in which structures, such as disciplinary societies, perform important functions. Finally, Karl Marx’s work suggests that we need to be attentive to the power struggles that occur between groups within societies and how these struggles change as material conditions change.

Disciplinary associations perform a number of important functions or roles. First, they are involved in the socialization of new members to the profession. In some cases, they exert formal control of educational institutions or certification of programs. In other cases, though, the socialization process is less formalized. Second, the association enables collective action by its members. Third, disciplinary associations can engage in an array of normative functions such as regulation of a profession or professional practice, including establishment of proscriptive ethical guidelines of members’ behavior. Finally, disciplinary associations can reward or punish members’ behavior in various ways.

These four functions are carried out via a number of mechanisms:

- conferences
- research
- journals

¹ Lisa M. Frehill, senior research analyst, Energetic Technology Center. The author is grateful for the skillful review provided by Daryl Chubin and Willie Pearson, Jr. Any errors that remain are her own.

- community/networking—web presence, membership directories, new online community technologies such as Twitter, LinkedIn, Facebook, affinity groups, etc.
- policy work, including advocacy
- scholarships, travel awards, research funds, internships

The relative importance of different functions may be reflected in the extent to which resources are allocated to these various mechanisms. Functions that are seen as important would tend to have a higher level of resource allocation than those functions that are less important.

Disciplinary associations vary greatly in terms of their characteristics. The geographic scope can be very large, such as the international level, or at world, regional, or national levels. This scope affects the extent to which the organization may become involved in policy and political issues, and at what level. The membership of disciplinary associations varies, too. In the sciences, some associations have a largely academic membership, such as the Association of Women in Mathematics, while others may have more industry members such as the American Chemical Society. Further, the extent to which students—graduate and undergraduate—participate in the activities of the society varies as well. Some associations are actually federations of many smaller organizations. For example the International Council for Science has 113 multidisciplinary National Scientific Members, Associates, and Observers (scientific research councils or science academies) from 133 countries.

It is also important to be attentive to the organizational structure and governance of disciplinary associations. Some, for example, have chapters at a “local” level, providing a mechanism for individuals to participate in activities without traveling. Many scientific associations have sections or other organizational entities that represent various sub-field or subject areas or interest groups. The balance of grassroots efforts versus centralization of tasks is an on-going struggle in some associations. As associations’ functions become more time- and labor-intensive, more of these functions are likely to be performed by professional staff rather than volunteers. Some associations are at the intersection of identity and profession. Social movement theory helps us understand the functions and mechanisms employed by these kinds of associations. In the United States, the very vibrant period of collective action by identity movements in the 1960s and 1970s—notably the Civil Rights Movements and the Women’s Liberation Movement—saw a blossoming of large organizational fields of associations connected by overlapping memberships and similarity of goals. Some of the organizations that arose in the sciences and engineering, include

- Association of Women in Mathematics (1971)
- Association of Women in Science (1971)
- National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (1972)
- Society of Hispanic Professional Engineers (1974)
- National Association of Black Engineers (1975)
- National Association of Black Physicists (1977)
- Association for Women in Computing (1978)

All of these organizations grew from grassroots organizing by members of the relevant identity groups—women, Blacks, and Hispanics—who saw a need to pursue common interests *vis-à-vis* their identity outside of existing disciplinary associations.

On the international and regional levels, however, the diffusion of the disciplinary association based on identity has been slow. Just as the U.S.-based organizations mentioned, above were grounded in identity movements in which women and minority scientists felt marginalized within their fields, some of the international women's organizations have their roots in the struggles against Western-dominated organizations. Examples of international women's science efforts include:

- International Network of Women Scientists and Engineers/International Conference of Women Engineers and Scientists (ICWES). First ICWES conference: 1964, organized by the U.S. Society of Women Engineers
- Gender and Science and Technology (1981)
- Third World Organization of Women in Science, now the Organization for Women in Science for the Developing World (1989)
- The Center for Arab Women for Training and Research (1993)
- Gender Advisory Board (1995)
- InterAcademy Council on Women in Science (2004)
- European Platform for Women in Science (2005)

Each of these organizations features meetings or conferences and multinational governing bodies. Beyond these mechanisms, associations seem to vary greatly in structure, form, web presence, and the like. Connections among these organizations and with U.S. disciplinary associations will be explored in more detail in future work.

Preliminary research about the role of U.S. disciplinary societies in increasing diversity in science and engineering was completed in 2008. The Commission on Professionals in Science and Technology (CPST), in partnership with the Association for Women in Science (AWIS), conducted a workshop for representatives from 24 disciplinary societies.² Attendees were from many types of associations and were involved in diversity efforts in different ways. In some cases, the attendees were from organizations like the Society of Women Engineers, in other cases they were from committees within a larger disciplinary association, such as the Women in Engineering Committee of the Institute for Electrical and Electronics Engineers. Prior to the workshop, an online survey was distributed to 120 people identified by AWIS and CPST as involved in efforts related to women, minorities, diversity, or some combination thereof to better understand the resources allocated to these efforts and the strategies used within disciplinary associations. With a 58 percent response rate, the findings are not considered capable of generalization but were a useful starting point, with results presented to the workshop attendees. Presentations were also made by several invitees, with all attendees informally sharing their work. Small group discussions and a final plenary discussion resulted in the following list of recommendations to U.S. disciplinary organizations:

- **Measure and assess the effectiveness of the society's current internal diversity efforts (e.g., staff, volunteers, and membership)**
 - Evaluate successes using goals and objectives
 - Pinpoint areas for improvement

² The Commission on Professionals in Science and Technology, "Recommendations from a Workshop: Professional Societies and Increasing Diversity in STEM," Boston, MA, February 14, 2008.

- Benchmark externally for best practices and establish mechanisms of accountability
- **Articulate the society's business case for diversity**
 - Define diversity and inclusiveness for the society
 - Outline how diversity supports the vision, mission, and goals of the society
 - Identify specific benefits to the society
- **Mainstream diversity**
 - Provide training and resources (e.g., staff support and funding) for diversity committees and caucuses
 - Continually educate and engage membership in diversity initiatives through surveys and communication vehicles; communicate survey results back to membership

The role and location of efforts to increase representation of women and/or minorities was an interesting point of discussion. Often an organization's resource allocations can be viewed as a symbol of commitment by its members. But in the case of diversity efforts related to identity, there are two other kinds of interpretations, suggesting that this could be an overly simplified view. On the one hand, members of various identity groups may be suspicious that the mainstream organization would co-opt their efforts at grassroots activities if they were dependent upon the support of the mainstream association. Another issue that was raised is also common: are the diversity efforts that are embedded within a larger disciplinary association genuine? Or do they represent a "cooling out," a process that merely placates identity group members but actually isolates and marginalizes their attempts to exercise voice within the association? These issues need to be explored further.

In closing, disciplinary associations are an important organizational structure through which scientists build communities of practice, rewarding achievements and enabling members to share information. As socializers of new occupational entrants, disciplinary societies impact the human resources pipeline into the workforce. Like any collective, though, disciplinary societies can serve as a conservative social force, replicating existing arrangements and hierarchies or they can be important loci of social change.

APPENDIX E-8

Promising Programs in Science: A Cross-National Exploration of What Works to Attract and Sustain Women

Daryl Chubin,¹ Catherine Didion,² Josephine Beoku-Betts,³ and Jann Adams⁴

“Best practice” is a term often uttered, but seldom achieved. “Best” compared to what? Measured how? In one cultural context or discipline—or many? The more realistic and attainable status of a program often is its “promise.”

“Promising programs” is a term popularized in the 2004 report from the public-private initiative known as BEST—Building Engineering and Science Talent. In its report, *A Bridge for All*, 124 university-based, undergraduate-centered STEM⁵ programs operating in the United States were reviewed, using the National Science Foundation (NSF) model of employing a panel of experts drawn from a range of relevant disciplines.⁶ This conceptual discussion is thus anchored by an empirical base that underscores the challenge before us. For we seek to look across cultural and political contexts to ask: What translates beyond disciplines and unique conditions to engender and sustain a promising intervention program?

There are many caveats and concerns to address. Above all, context matters! While effective programs are a universal vehicle for intervening in the status quo, any program is embedded in a particular national and local cultural context. Furthermore, sponsors, program organizers/leaders, and the population they are intended to serve bring different expectations to the programs in which they participate. This is no less the case for programs aimed at women’s educational transitions and their articulation with employment structures and opportunities.

A robust literature on differences in preparation and participation by certain populations—women, members of racial/ethnic groups, and those with other significant characteristics of “difference” (visible or non-apparent)—reveals the unevenness (due to residence, education, bias, tradition, etc.) of what Max Weber called “life chances.”⁷ Social inequalities give rise to the need for programs to those underserved.

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³ Josephine Beoku-Betts, director, Women’s Studies Center at Florida Atlantic University.

⁴ Jann Adams, associate professor of psychology and associate dean of the Division of Science and Mathematics, Morehouse College.

⁵ Science, technology, engineering, and mathematics (STEM) is a commonly used acronym in the United States.

⁶ For details on the methodology and analysis, see BEST, 2004. *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering, and Mathematics*. San Diego, CA: BEST [online]. Available at http://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdFINAL.pdf.

⁷ For example, on women in science as an underserved population, see National Research Council. 2007. *Beyond*

Programs—Caveats and Concerns

Even when a program is created, its design may differ from implementation. Flaws in either case harbor implications for the future: Will the program thrive long enough to be institutionalized locally, adapted and transferred to similar populations in other sites, and perhaps scaled to serve different populations and contexts? “Sustainability” is often used as a test of impact. If so, then we tend to call the program a “success;” if it cannot survive beyond its original outside funding and leverage other resources to continue with succeeding cohorts of participants, the program fades and is considered a failure.

Of course, such ideal-types are rigid and beg many questions, including differing expectations, measures of impact and success, and the role of program leaders and practices. In short, all programs—even the best ones—evolve. Can we capture their “life cycle,” identify similarities and differences in program content and sequence, distinguish intentions (design) from behavior (implementation) to evaluation (measurement)?

What does the program do? What is its core character and purpose? Any program should cite evidence that supports whatever is planned as a means of advancing the policy or mission of the organization offering it, and should be tailored to accomplish that goal.

How the program is executed on behalf of the served population is a translation of grand plans into on-the-ground delivery of services.

Following BEST as a template, we can employ a small set of criteria as a “wish list” for judging empirically what a promising program should entail. Those criteria would include

- the form of intervention (typically more than one kind of activity) designed to produce a desired outcome;
- a specified target population;
- a track record of minimally five years of operation;
- evidence of positive outcomes (ideally documented through third-party evaluation or a research study, preferably with a comparison group); and
- findings that inform the operation of similar programs.

If *all* of these criteria are viewed as requirements for what constitutes a promising program, and not as a menu from which program organizers can pick-and-choose, then we conclude that few programs qualify. In the BEST population, less than 10 percent of the nominated programs passed muster as “promising” or “exemplary” according to the expert review panel. Clearly, funding and leadership are keys to longevity. However, the environment must be receptive to moving a “soft-money” project into an organization’s operating budget. This transition signals that a marginal effort by a few contributes to the mainstream of the organization’s mission, thereby warranting “hard money” support.

Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering. Washington, D.C.: The National Academies Press. On minorities in science, see National Research Council. 2011. *Expanding Underrepresented Minority Participation: America’s Science and Technology Talent at the Crossroads.* Washington, D.C.: The National Academy Press.

Program Case Studies—Developing and Developed Worlds

To demonstrate variations across cultures, we highlight case studies of two successful programs. One comes from the developing world and one from the developed world.

The Organization for Women in Science for the Developing World (OWSDW, formerly the Third World Organization for Women in Science, or TWOWS), was launched as an international non-governmental organization established in 1989. The TWOWS/OWSDW Postgraduate Training Fellowship Program was established in 1998, and has funded young women scientists under the age of 40 to secure postgraduate training in centers of research excellence in the global South.⁸

The Training Fellowship program demonstrates excellence of the host training institutions in the global South. Africa is disproportionately represented among countries applying for and receiving awards, compared to the Asia and Pacific Regions and Arab Regions. The domination of Nigeria among fellowship applicants and recipients of the award suggests a problem of effectively accessing the targeted population. A majority of former Fellows are now working in university research institutes in Africa, even though they may not be in their home country. Thus, the program has generated some amount of South to South exchange, stemming to some extent the problem of “brain drain” to the North. Though uneven in impact, it has been particularly successful in launching careers of women scientists.

Perhaps the most promising gender-conscious science and engineering faculty-focused program in the United States is NSF’s ADVANCE program. Established in 1995, the goal of ADVANCE is to increase diversity in the science, technology and engineering workforce by increasing representation and advancement of women in the professoriate. We do not look at this program from the NSF perspective, but rather through the eyes of two mature ADVANCE projects (one at the University of Michigan, the other at the University of Wisconsin).⁹ For our purpose, the focus is on two project examples, initiated in 2001, as mature, indeed “graduated” ADVANCE projects that illustrate how an externally-funded program can be adapted to change the structures of the institution in which it is implemented. This is what NSF calls “institutional transformation.” ADVANCE principles have migrated to the core of few U.S. research universities, while most still struggle with sustaining the drive toward transformation.

For example, Michigan’s ADVANCE program produced an increase in the number of tenure-track women hired. Additionally, nine women were appointed to departmental chair positions. Foremost among the key interventions, the committees that managed ADVANCE were composed of 45 senior faculty members and administrators who became “organizational catalysts” for change.¹⁰ Sponsorship by NSF lent credibility to the effort as an institutional initiative to improve science research. The target of the intervention was the institutional culture, not the women in the academy. The Wisconsin ADVANCE program focused on institutional “climate.” Eleven “climate indicators” assessed individual faculty perceptions of how respected

⁸ For more information on the TWOWS/OWSDW Postgraduate Training Fellowship Program, see: <http://owsdw.ictp.it/>.

⁹ Meyerson, D. and M. Tompkins. 2007. “Tempered Radicals as Institutional Change Agents: The Case Advancing Gender Equity at the University of Michigan.” *Harvard J. Law Gender*. 30:303-322; and Pribbenow, C.M., J. Sheridan, B. Parker, J. Winchell, D. Benting, K. O’Connell, C. Ford, R. Gunter, and A. Stambach. October 8, 2007. Summative Evaluation Report of WISELI: The Women in Science and Engineering Leadership Institute.

¹⁰ Sturm, S. 2006. “The Architecture of Inclusion: Advancing Workplace Equity in Higher Education.” *Harvard J. Law Gender*. 29:247-289.

they felt by their colleagues, students, staff and chairs; how included, valued, recognized or isolated they felt; and whether they believed they “fit” in their departments.¹¹ In short, women faculty felt that the departmental “climate” was more negative than did their male counterparts. And the university instituted a series of intervention workshops for chairs and senior faculty that improved both awareness and perceptions of a more supportive campus climate.

With our two case studies in mind, we could fashion a matrix of criteria (not presented here) for assessing how promising other programs appear to be. Such a matrix is a research summary that can be used as a kind of scorecard of STEM intervention programs directed to increasing the number and improving the experience of participants. Entries in the cells mark progress toward fulfillment of each criterion. The criteria would include years of operation (5+), multiple interventions, and evidence of outcomes.

Life Cycle of Programs and Beyond

Structures and practices that endure reflect the life cycle of programs. Those that contribute to achieving institutional goals tend to be retained and made available to all. Such “mainstreaming” signifies—strange as it sounds—the institutionalization of change. Beyond the local institution, such changes should have applicability to other similar institutions. This process of adaptation—the language of “adoption” denotes a too-linear transfer of knowledge and practice without integrating these cultural changes into a new setting replete with its own traditions—is a means of spreading and scaling “what works.”¹² Scale-up is difficult work. Organizations tend to resist innovations that come from outside “their own backyard,” not of their own invention or without campus advocates with credibility.

In an effort to move systematically from program context to description to inference, we are engaged in the academic equivalent of converting theory to practice. Documenting program characteristics is but a step toward understanding why interventions have produced differences in participation among any underserved group in science.¹³ This is where research transcends evaluation and influences stakeholders in sponsor, performer, and policy-making communities to recognize promising programs.

In sum, a program can be conceptualized, rationalized, and described as an organized response to a problem around which people coalesce. How they implement the response will determine whether or not it reaches the intended audience and has the intended effects. Through research and evaluation, program leaders learn about the strengths and weaknesses of their interventions—what is working, how to modify activities, magnify impacts, expand reach, and measure with greater precision. The sum of these adjustments creates a program history and with it accountability to sponsors and host institutions who respect “promise.”

¹¹ Sheridan, J., C. Pribbenow, E. Fine, J. Handelsman, and M. Carnes. June 2007. “Climate Change at the University of Wisconsin-Madison: What Changed and Did ADVANCE have an Impact?” *Women in Engineering Programs and Advocates Network 2007 Conference Proceedings*.

¹² Fox, M.F., G. Sonnert, and I. Nikiforova. 2007. “Successful Program for Undergraduate Women in Science and Engineering: Adapting versus Adopting the Institutional Environment.” *Res. Higher Ed.* 50:333-353.

¹³ Chubin, D.E., A.L. DePass, and L. Blockus, eds. 2010. *Understanding Interventions That Broaden Participation in Research Careers 2009: Embracing a Breadth of Purpose*, Vol. III. Available at www.UnderstandingInterventions.org.

APPENDIX E-9

Promising Policies

Cheryl B. Leggon,¹ and Connie L. McNeely²

Traditionally, policy discussions regarding the role of women in science, technology, engineering, and mathematics (STEM) typically turned on questions of social justice, equity, and rights. However, the dominant rationale today for enhancing and increasing women's representation in STEM fields has shifted to a focus on workforce needs and overall economic and national development. The expansion of the modern knowledge-based and innovation-driven global economy has emphasized related workforce demands in countries around the world which, in turn, have brought attention to populations that traditionally have been underrepresented in that workforce. In this vein, STEM women have become an increasingly prominent issue on policy agendas. While social justice and rights still are underlying factors in many debates regarding the position of women in society, more material labor market and workforce concerns now constitute the core of policy dialogues addressing gender relations and outcomes in STEM fields. Accordingly, we focus on related issues to examine promising policies for advancing women in science as a critical problem around the world.³

CONCEPTUAL DIMENSIONS

We begin by conceptualizing “policy” in three major ways as plan, rationale, and intervention. As *plan*, policy delineates aims and provides related guidelines for action—or inaction. As *rationale*, policy justifies and/or supports a course of action or inaction. In terms of women's participation in the sciences, a wide range of themes can be identified in terms of policy as rationale. For example, an enduring fundamental issue involves questions of the role of women in society and of their capacity for understanding and conducting science. The relationship between women and education was the rationale first for exclusion, and then for inclusion—specifically, the erroneous belief that education negatively impacted childbearing and the subsequent argument that educating women would lead to better-raised children both have been invoked as policy rationales. As *intervention*, policy is conceived as a plan of action for changing specific outcomes deemed as undesirable in some way. Moreover, as plan, rationale,

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³ Although this project focuses on women in chemistry, computer science, and mathematics and statistics, relevant policies tend to reference STEM in general. Thus, we explore the general policies, while recognizing their application to women in the specified fields.

and intervention, policy is not developed in a vacuum, but rather in a broader context shaped by political, economic, and cultural forces. Consequently, policy is not static; policy is the product of various interconnected and interdependent dynamic factors and processes. Furthermore, because “one size does not fit all,” a policy that is promising in one context may not necessarily be promising in another.

Accordingly, we consider various aspects of policy as they relate to one another and, by so doing, provide a means for systematically comparing and categorizing policy goals and provisions cross-nationally and over time. From these systematic comparisons, we identify a range of policies that show promise in the context of individual countries and regions. From these policies, we search for common patterns and characteristics, and also note differences relative to situational or contextual conditions. Our discussion of promising policies is based on the premise that policies address issues as well as problems—and that all issues are not problems. Therefore, policy can address what is working as well as what is not working. Thus, framed as plan, rationale, and intervention, and with particular attention to encouraging female STEM participation, promising policies reflect a process that can be delineated in terms of six general analytical dimensions: issue identification, statement, data, gender mainstreaming, institutionalization, and diffusion.⁴

Problem and Issue Identification

To maximize effectiveness, policy must be based on a clear specification of a problem or issue, including the scope of the issue and the magnitude of its ramifications. Most essentially, there should be an indication of the segment(s) of the population that the policy is meant to impact and in what way(s). Problem and issue specification must be carefully crafted and articulated to capture the essential policy traits and features and to channel them to frame the issue accordingly. This task is especially essential in light of different legal and cultural contexts and applications across and within countries, which leads to some basic questions that must be considered. For example, to what extent do policy goals and projections intended to increase female representation in science and technology also include references to their increased presence as decision-makers and evaluators—positions that function as social and professional arbiters and community gatekeepers?

Policy Statement

Promising policies couple the policy statement to policy implementation. Clear specifications of objectives provide directives for implementation and promising policies focus on actions that are goal-oriented. Moreover, along with guidelines for action, they establish targets rather than quotas. Enhancing women’s participation—i.e., mainstreaming women’s participation—in all aspects of the sciences and technology requires continuous and rigorous monitoring over time. Therefore, the policy statements characteristic of promising policies delineate deadlines for specified progress, and emphasize the obligation to report the extent of

⁴ Our approach is informed by that of the Building Engineering and Science Talent (BEST) initiative, a public–private partnership dedicated to building a stronger, more diverse U.S. workforce in science, engineering, and technology by increasing the participation of underrepresented groups. BEST applies its knowledge of program effectiveness in STEM to support efforts to build capacity at the local, state, and federal levels. Available at <http://www.bestworkforce.org>.

progress made towards long-term policy goals and shorter-term objectives (benchmarks). Promising policies explicitly address issues of accountability in terms of policy implementation, monitoring, and evaluation.

Relevant Data

Evidence-based policies are required for legitimating an action framework as plan, rationale, and intervention. Accurate, credible, reliable, and valid data, act to both drive and inform promising policies, reflecting interactive and iterative processes. To that end, data must be engaged and disaggregated in ways consistent with the specification of the policy issue or problem. Thus, in the context of this project, data should be disaggregated not only by gender but also by citizenship, race, ethnicity, and other relevant socio-cultural, political, and economic characteristics. This applies to countries in the “developed” world as well as to those in the “developing” world. Such data provide a foundation from which policy can be developed and implemented. Furthermore, these data form the basis for policy evaluation and are the building blocks of adequate and appropriate indicators of policy efficacy at various points in time. In the same vein, data can provide real time feedback during implementation, enabling adjustments as warranted.

Gender Mainstreaming

With gender equality as the ultimate goal, gender mainstreaming is a strategy for assessing the implications for women and men of policies and programs, treating gender perspectives as integral to the design, implementation, monitoring, and evaluation of policies and programs in all political, economic, and social spheres (United Nations [UN] 1997). Accordingly, whether on the national, regional, or international level, promising policies have statements that explicitly tie gender mainstreaming to social and economic development. For example, rather than a general statement about the importance of educating all citizens for the good of the nation, promising policies clearly and unequivocally identify women as a specific policy category, stating that women must be educated in general—and, for our purposes, in STEM in particular—to enhance a country’s growth and international competitiveness.

Sustainability and Institutionalization

Sustainability and institutionalization are inextricably intertwined. Promising policies are sustainable—i.e., they can be maintained and supported over time relative to policy implementation, goals, and outcomes. In this sense, sustainable development policies meet the needs of the present without compromising the ability of future generations to meet their own needs (UN 1987). Thus, promising policies that focus on, for example, improving education for all, as well as enhancing women’s participation in science and technology, are strategies for more sustainable development (Cohen 2006). Promising policies are sufficiently flexible to adjust to economic, legal, social, and political changes in the policy environment. Moreover, such policies are institutionalized—i.e., they become part of the standard operating processes and procedures of an organization or country.

Diffusion

Promising policies also can provide general models for action in terms of plan, rationale, and intervention. From these policies, certain principles and processes can be adapted and applied across contexts and geographic boundaries. The international context is strategically significant for regional and national organizations operating as policy actors and sources of policy ideas, policy agenda setting, and policy formulation, implementation, and evaluation. Similarly, national and regional level policies can inform and drive policies in other countries and regions around the world.

ANALYTICAL APPLICATIONS

As exemplified in Figure E-9-1, these analytical dimensions are reflected in substance and action through various organizations and stakeholders operating at different levels of analysis, effecting policy through relational processes and interaction. Note that, although we emphasize policy processes in countries and organizations at national and international levels, these dimensions and considerations are applicable across institutional settings. Thus, policy concerns at provincial or local levels and within specific agencies and organizations (e.g., universities and firms) can be approached in similar ways, especially given questions of horizontal and vertical policy implementation.

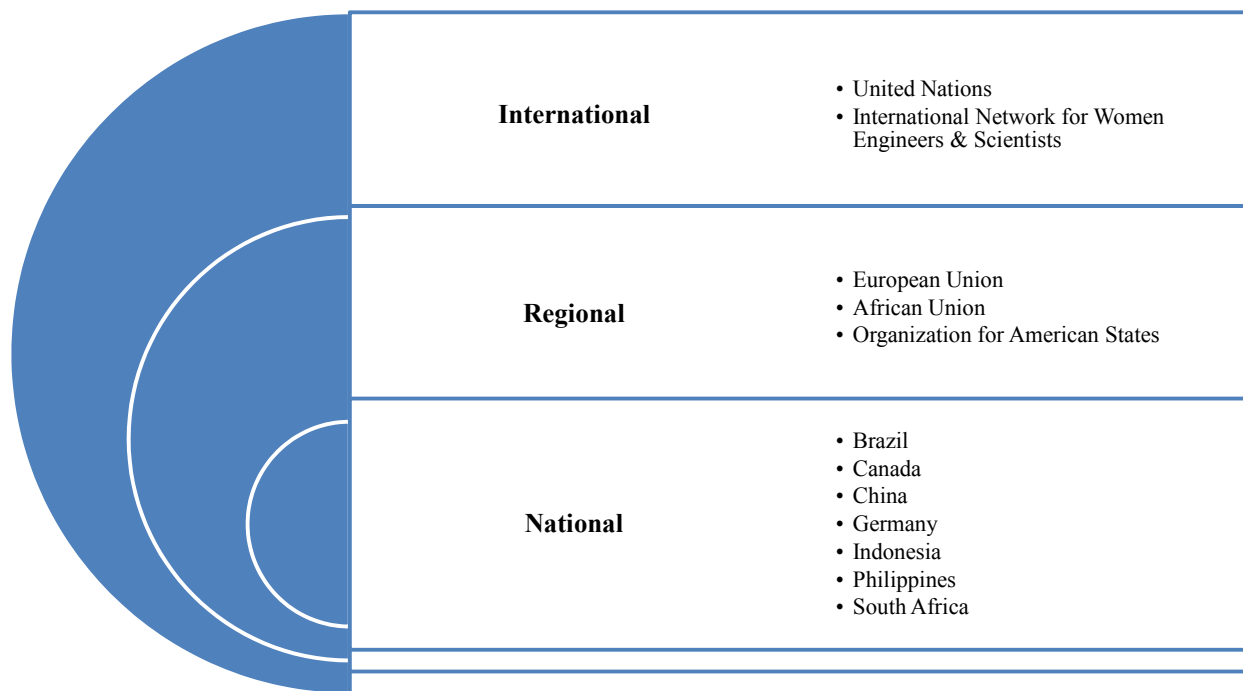


FIGURE E-9-1. Examples of Policy Levels of Analysis and Actors

Moreover, the international context can provide leverage for and lend credibility to policies being proposed in individual and/or groups of nations. Frequently, initiatives begun by some component of the UN are adopted by individual nations and/or consortia of nations.

Similarly, regional organizations can be sources of policy ideas and models for individual members. For example, to belong to the European Union, a country agrees to participate in/adopt certain policies, programs, and platforms as a condition of membership.

Based on a review of representative policies, we identified the major defining characteristics of promising policies that focus on enhancing and increasing women's participation in STEM, with particular applicability to chemistry, computer science, mathematics and statistics. Using these characteristics, we developed an operational framework for a comparative assessment of promising national policies. As an illustration, Table E-9-1 presents a simplified view of relevant policy characteristics in selected countries drawn from individual policy case studies.

TABLE E-9-1. Examples of Major Promising Policy Characteristics in Selected Countries

	Informed and Driven by Data	Monitoring	Gender Mainstreaming	Sustainability Institutionalization
Brazil			X	
China			X	X
Germany		X	X	
Philippines		X	X	X
Vietnam		X	X	

Policy Challenges and Opportunities

Although arguments abound that no country can afford to exclude more than half of its population—women—from its STEM education and workforce processes, the situation has remained critical with rampant disparities still apparent to varying degrees across countries. Although some lack of awareness of the significance of the role of women in STEM for development exists, there is a general recognition that “the difficulties encountered by women, constituting over half of the world’s population, in entering, pursuing, and advancing in a career in the sciences and in participating in decision-making in science and technology should be addressed urgently” as fundamental issues of national development and progress.⁵ Yet, around the world, women are still underrepresented in STEM education and training, in research and development, in STEM careers, and in related policy and decision-making positions (United Nations Educational, Scientific, and Cultural Organization [UNESCO] 2003, 2004). Accordingly, several policy challenges remain relative to increasing female involvement in STEM fields.

Remaining foremost among policy challenges across various countries are activities aimed at strengthening STEM education for all parts of their populations and facilitating the participation of women and other underrepresented groups in the STEM workforce (UNESCO 2007). Although some variation exists by country and field, STEM disciplinary cultures—especially in chemistry, computer science, and mathematics and statistics—have reflected male bias, as indicated by the marginalization and low enrollments of women in STEM in universities and research institutions. Not surprisingly, when allowed the opportunity, girls and women evince high performance in STEM fields across the board (European Commission [EC] 2000).

⁵ From UNESCO’s Declaration on Science and the Use of Scientific Knowledge (in Cetto 2000, p. 466).

However, even in countries where more women are increasingly earning advanced degrees in STEM fields, for the most part those increases are not reflected in the STEM professions themselves; the STEM sector loses vital female participation postgraduation, showing the need for policy action (cf. Blättel-Mink 2009, p. 105). Moreover, while female degree attainment in STEM fields has increased in many countries, many of the world's women still face social, cultural, and economic barriers to participation. To break these barriers, policies reflecting government commitment and support are crucial.

Social and cultural barriers represent some of the greatest impediments to gender equality in the sciences. Related norms dictating preferential treatment of boys and men and general discrimination and disparaging attitudes towards females create negative situations for advancing women in science. In many countries, girls and women are discouraged and even physically prevented from educational attainment and workforce participation. Despite recommendations against gender bias, especially for promoting development, it is not unusual for females to be socially disadvantaged in STEM attainment. In many countries, the problem is not merely to attract women to STEM fields, but, even more to the point, to transform male (and female) attitudes and to remove other societal barriers and constraints to their participation in STEM. Because politics sets the context for policy action, the interests of different stakeholders may not be aligned and may even be antithetical to one another. Consequently, successful policy-making often must be treated as a balancing-act.

Also prominent on the policy agenda is the need to develop analytical frameworks and to collect relevant and reliable data to account for the complexity of the relationships between STEM education and the STEM workforce and to assess the impact of specific policy efforts. Valid metrics and expanded relevant data collection are crucial for effective policy planning and for both monitoring and evaluating policy initiatives. Development strategies have been based on policies aimed at promoting gender equity and eliminating STEM gender disparities, and reliable data are essential for policy development and assessment at all levels. The European Commission has gone a long way in developing metrics to assess gender equality in science and technology, and indicates that “the presence of certain equality measures is linked with the rates of participation of women in science” (EC 2008, p. 8).

With both developed and developing countries asserting the need for STEM experts, policies cannot be confined to working only at the national level (cf. Blättel-Mink 2009). National and international networks are critical for the institutionalization and diffusion of promising policies and effective efforts. While acknowledging striking differences among countries and regions in regard to gender participation in STEM and society more generally, international and regional groups can promote the formulation of STEM development policies that encompass gender considerations. Accordingly, international organizations, both governmental and nongovernmental, play especially significant roles in networking and policy diffusion. As an international organization, UNESCO has long been committed to promoting equal access to education, to increasing the participation of women in STEM fields, and encouraging their access to scientific and decision-making bodies. Thus, for example, recognizing that women's talents have been underrecognized and underutilized in most countries, UNESCO has promoted the establishment of national committees on gender, science, and technology for assessing and promoting gender mainstreaming in STEM-related policies. While its member states ostensibly have signed on to pursue related policies, their capacity to follow through, not to mention their political and institutional will to do so, can vary widely.

Again, it is generally acknowledged that realizing the potential of science and technology for national socioeconomic development requires using all segments of a country's population (UNESCO 2007). However, women remain the least incorporated into the STEM workforce, which translates into a significant loss of scientific human capital for development.

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