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Gender, Science and Technology

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[*] The views expressed in this paper are those of the author and do not necessarily represent those of the United Nations.
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A. INTRODUCTION

Science and technology (S&T)[2] has long been recognized as a driving force for economic development and for improving the well-being of individuals and their communities. In this context, it is important to look at the various linkages pertaining to gender, science and technology. A well-known issue is the persistent underrepresentation of women in S&T. This underrepresentation is present throughout the life course, from primary through tertiary education to employment in different sectors. Even fewer women progress in their careers to decision-making positions. The dearth of women scientists and engineers is often considered a 'pipeline' problem, which implies that a solution would be to train more girls and women in S&T. Years of research and experience have shown, however, that efforts to achieve equal participation for women in S&T will not be successful without reform of gender divisions of labour in society at large and in scientific institutions specifically.

Exclusion of women as researchers and innovators represents more than a loss of talent and skilled labour. It also represents the exclusion of the specific types of knowledge women develop and maintain as a consequence of gender roles. For example, women are responsible for food production and medical care in much of the developing world, and consequently possess unique intellectual resources (such as knowledge about the medicinal properties of plants) as well as material resources (such as seeds for specific strains of crops).[3]

In addition, gender biases built into society and research institutions create gender biases in S&T knowledge production. Gender bias in research limits the objectivity and excellence of S&T, and hence its potential benefits to society. For example, women are often left out of basic engineering design. Automobile crash test protocols consider short people (mainly women, but also many men) to be 'out-of-position' drivers because they sit too close to the steering wheel. 'Out-of-position' drivers are more likely to be injured in accidents. [4]

Another issue is women's unequal access to basic technologies. Women in many parts of the developing world spend large amounts of time performing labour-intensive tasks, such as carrying water long distances. Water sources close to home, mechanized grain mills, and energy efficient stoves remain out of the reach of many women.[5] When women gain access to time- and labour-saving technologies, productivity increases and girls are more likely to receive the education required for participation in a knowledge-based economy.[6]

This paper provides background information on current efforts to achieve gender equality for girls and women in S&T education, employment, research, and decision-making.

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[2] In this paper, 'science' refers to the natural sciences; the social sciences and humanities are specifically excluded.

[3] World Intellectual Property Organization. (2006). WIPO Addresses Indigenous Issues at UN Forum. *WIPO Magazine*, August (4).

[4] Hallman, J., Yoganandan, N., & Pintar, F. (2008). Torso Side Airbag Out-Of-Position Evaluation using Stationary and Dynamic Occupants. *Biomedical Sciences Instrumentation, 44*, 123-128.

[5] Gill, K., Brooks, K., McDougall, J., Patel, P., Kes, A. (2010). *Bridging the Gender Divide: How Technology Can Advance Women Economically*. Washington, D.C.: International Center for Research on Women, *2*, 3.

[6] Boserup, E., Kanji, N., Tan, S., & Toulmin, C. (2007). *Woman's Role in Economic Development*. London: Cromwell Press.

B. ACADEMIC AND POLICY APPROACHES

Academics and policymakers have used several theoretical and policy approaches to understand, and attempt to rectify, gender inequalities in S&T.

> ***Sex*** refers to biological characteristics that define females and males. ***Gender*** refers to the rules, traditions, and social relationships in cultures that together define and sanction feminine and masculine behaviour. Gender relations also determine how power is allocated between, and used by, women and men.

1. Theoretical approaches

a. Gender-neutral approach (1970s-present)

Basic tenets:

- Supports equal access for women and girls to education and employment.
- Considers S&T objective, universal, and unbiased.

Problems:

- Considers S&T sex- and gender-neutral.
- Tends to ignore *sex* and *gender* differences.
- Locates problems in women (their education, socialization, aspirations, and values). To achieve success, women or girls are often required to assume male values, behaviours, and life rhythms.
- Tends to transfer Western-style science models to developing countries.

b. Difference approach (late 1980s-present)

Basic tenets:

- Emphasizes sex and gender differences between men and women.
- Identifies bias in S&T by seeing what is left out from the feminine side of life.
- Opens definitions of science to include non-Western science and local knowledges (also referred to as indigenous or traditional knowledges).

Problems:

- Tends to romanticize traditional masculinity and femininity, and to play into conventional gender stereotypes.
- Fails to take into account that men and women across classes and cultures hold many different perspectives and values.
- Tends to essentialize gender characteristics and impute positive traits, such as nurturing, to women. By seeing women and female values as key change agents, this approach can exclude men.

c. Equality approach through gender analysis (2000-present)

Basic tenets:

- Employs gender analysis as a *resource* to enhance scientific excellence.
- Mainstreams methods of sex and gender analysis into S&T policy and research.
- Refutes the notion that increasing women's participation will automatically lead to gender-sensitive science and technology. Everyone—men and women—can and must be trained in sophisticated methods of sex and gender analysis.

- Examines intersections of gender, race, and ethnicity.
- Seeks methods of sex and gender analysis relevant for both Western-style and local knowledges.

Problems:

- Methods of sex and gender analysis are only now being codified.
- Scientists, engineers, and policy makers are unfamiliar with methods of sex and gender analysis.
- Methods of sex and gender analysis are not yet mainstreamed into S&T curricula.

2. Past commitments and recommendations

Governments have met at international conferences and made commitments to increase women's and girls' access to and participation in S&T. These include:

- **Beijing Platform for Action (1995)**

  The Beijing Platform for Action, adopted at the Fourth World Conference on Women (1995), calls on Governments and all stakeholders to increase girls' and women's access to and retention in science and technology, including by adapting curricula, and teaching materials (paras. 83 (g) and 83 (f)). Importantly for this expert group meeting (EGM) considerations, the Platform also urges stakeholders to promote gender-sensitive and women-centred health research, treatment, and technology, and to integrate traditional and indigenous knowledge with Western medicine (para.109 (b)), as well as to create training, research, and resource centers that disseminate environmentally sound technologies to women (para. 258 (b)(v)).[7]

- **Budapest Science Agenda and Framework for Action (1999)**

  The Budapest Agenda for Action, adopted at the World Conference on Science (1999), calls on government agencies, international organizations, and research institutions to ensure the full participation of women in the planning, orientation, execution, and assessment of research activities. The Agenda further calls for women to become active participants in shaping the future direction of scientific research (3.3(1)).[8]

  The Budapest Agenda also calls on governmental and non-governmental organizations (NGOs) to sustain traditional knowledge systems through active support of the keepers and developers of this knowledge. The Agenda notes that such support requires protection of native languages, ecological conservation, and recognition of women's traditional knowledges (3.4(4)).

  Finally, the Agenda urges that national education systems develop new curricula, teaching methodologies, and resources that take gender and cultural diversity into account (2.4(3)).

In addition to the commitments made by Governments, recommendations have been developed in other forums. The Gender Advisory Board of the United Nations Commission on Science and Technology for Development, for example, developed the following 'Transformative Actions':

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[7] United Nations, Division for the Advancement of Women. (2010). Aide-Memoire for Expert Group Meeting on Women's and Girl's Access to and Participation in Science and Technology, 18 June.

[8] UNESCO World Conference on Science. (1999). Science Agenda—Framework for Action, Budapest, Hungary, 16 June – 1 July.

1. Establishing gender equity in science and technology education
2. Removing obstacles to women in scientific and technological careers
3. Making science responsive to the gender dimension
4. Making the S&T decision-making process more gender aware
5. Relating better with local knowledge systems
6. Addressing ethical issues related to gender in science and technology
7. Improving the collection of gender-disaggregated data for policy-makers
8. Equal opportunity for entry and advancement into larger-scale science, technology, engineering, mathematics disciplines (STEM) and innovation systems.[9]

3. Policy approaches

Interventions to promote gender equality in S&T can be classified in three main policy approaches The first of these approaches focuses on programmes targeting girls and women themselves in order to increase their participation in S&T. The second approach seeks to increase girls' and women's participation by reforming scientific and educational institutions. The third focuses on overcoming gender bias by mainstreaming gender analysis into S&T. These three policy approaches are interrelated: increasing the numbers of girls and women in science and technology will not be successful until institutions are restructured and gender analysis is mainstreamed into knowledge production.

a. Girls and women. Increasing participation in science and technology

The first and most straightforward approach focuses on programmes to increase the participation of girls and women in S&T education and employment. The rationale is that the dearth of women scientists and engineers is a 'pipeline' problem and that more girls and women needed to be trained in S&T fields.

In the 1980s, national governments and international agencies began collecting sex-disaggregated data to track female participation levels in science and engineering. In 1982, the United States National Science Foundation (NSF) published the first congressionally mandated report, *Women and minorities in science and engineering*, to which persons with disabilities were added in 1984.[10] In 2003, the European Union (EU)'s Directorate-General for Research (DG Research) published its first *She figures*, reporting trends in women's participation across its member states.[11] The United Nations Educational, Scientific, and Cultural Organization (UNESCO)'s Institute for Statistics collects data on girls' and women's access to education and research globally.[12] However, data collection practices still vary considerably between nations. Databases are currently inconsistent and do not allow for high-quality international comparison. Further, there is a need for more exact data on women's participation in particular subfields of

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[9] United Nations Center for Science and Technology for Development (UNCSTD) Gender Advisory Board. (2006). Gender Working Group: Transformative Actions. New York: United Nations Press.

[10] National Science Foundation. (1982). *Women and Minorities in Science and Engineering.* Washington, D.C.: National Academies Press; National Research Council. (2009). *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty.* Washington, D.C.: National Academies Press.

[11] European Commission. (2003). *She Figures*. Luxembourg: Office for Official Publications of the European Communities.

[12] UNESCO. (2007). Head Counts and Headaches: Measuring Women in Science. *World of Science, 5 (2)*, 21-23.

science. Greater standardization and transparency are needed to better monitor areas where inequalities persist.

Governments also established programmes to support women's careers in S&T. In 1989, for example, the NSF established a Task Force on Programs for Women that increased funding to women researchers, taught women negotiation skills, and set up mentoring networks.[13] The European Union recommended similar measures in its 2000 European Technology Assessment Network (ETAN) report.[14] The Republic of Korea has actively promoted women's participation in science, engineering and technology (SET) since 2002, for example by supporting data collection to identify SET fields with low female participation, setting quotas for women project managers, and funding academic faculty positions for women.[15]

Civil society groups have also taken up this approach. For instance, the Third World Organization for Women in Science, formed in 1989 and renamed the Organization for Women in Science for the Developing World (OWSDW) in 2010, is an international forum uniting eminent women scientists from the developing world with the objective of strengthening their role in the development process and promoting their representation in scientific and technological leadership. To further these goals, the OWSDW provides, for example, postgraduate training fellowships for women scientists from Sub-Saharan Africa and Least Developed Countries at Centres of Excellence in the South.[16]

This first policy approach seeks to increase women's participation in S&T by supporting girls' education and women's careers. While critically important, this approach has also been criticized for 'fixing the women'—attempting to give women more education, more research money, and more training to better assimilate them to traditionally male domains. The implicit assumption is that S&T institutions and research are gender neutral. Consequently, this approach fails to look beyond women's careers to reform S&T institutions and research methods. Achieving equality requires examining gender divisions of labour in society at large and in science specifically, as well as considering how research is conceptualized and carried out.

b. Institutions and societies. Transforming structures.

The second general policy approach seeks to increase women's participation by reforming scientific and educational institutions. To the extent that Western-style science has been replicated around the world, institutional structures, cultural stereotypes, and social divisions of labour disadvantage women's participation. In 2001, the United States NSF launched its robust ADVANCE programme to help institutions implement structural changes in classrooms and laboratories to improve women's and minorities' success in science and engineering. These efforts reform institutions that historically developed around the needs of male professionals with stay-at-home wives. Institutional reforms range from counteracting subtle gender and ethnic biases in hiring and promotion practices to restructuring work/life balance by offering parental leave, supporting child- and elder-care, and allowing for career breaks.[17] The Republic of Korea

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[13] Organization for Economic Cooperation and Development. (2006). *Women in Scientific Careers*. Paris: OECD Publishing.

[14] ETAN Expert Working Group. (2000). *Science Policies in the European Union*. Brussels: European Commission.

[15] Lee, K-J-B. (2010). Women in Science, Engineering and Technology (SET) in Korea: Improving Retention and Building Capacity. *International Journal of Gender, Science and Technology, 2 (2)*, 235-248.

[16] Organization for Women in Science for the Developing World. (2010). Fourth General Assembly of the OWSDW, Beijing, China, 27 June – 30 June.

[17] NSF ADVANCE Program (2009). Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers.

These three policy approaches are interrelated. Increasing girls' and women's participation in science and engineering will not be successful until institutions are restructured and gender analysis is mainstreamed into knowledge production.

implemented its Women in S&T-Friendly Institutional Transformation project, modeled on the NSF ADVANCE programme, in 2004. The goal of this programme is to promote women by developing family-friendly work environments.[18]

In India, where in 2000 women constituted only 7 per cent of total faculty across India's top four science and engineering academic institutions, a new report from the Academy of Science, Bangalore, has set out 13 policy recommendations to reform institutions and prevent the loss of trained scientific 'womanpower'. These include mandating at least 33 per cent women on all decision-making committees and implementing programmes to accommodate spouses working in the same field of study.[19]

This second policy approach focuses on restructuring institutions while assuming that what goes on inside institutions—research and knowledge production—is gender neutral. Restructuring institutions is important, but must be supplemented by efforts to eliminate gender bias from research and design.

c. Knowledge. Enhancing excellence by mainstreaming gender analysis into S&T research

The European Union's DG Research is the global policy leader in mainstreaming gender analysis into research. In the 6th Framework Programme for Research and Technological Development (FP6, 2002-2006), DG Research required that all S&T grantees include a 'gender dimension' in their research. As stated in the call for proposals, research design must specify "whether, and in what sense, sex and gender are relevant in the objectives and in the methodology of the projects".[20] The EU's 2003 *Vademecum: Gender mainstreaming in the 6th framework programme* offered guidance to programme officers on how to structure the competitive grant process to ensure that gender analysis is included in basic research. The European Union scaled back its cutting-edge research requirement in its FP7 (2007-2013). While using gender analysis in research is retained, compliance has not been enforced because too few S&T researchers know how to use gender analysis in their work.[21] DG Research currently seeks to train researchers in how to integrate gender analysis into research.[22] DG Research is one of the few S&T research

[18] Lee, K-J-B. (2010). Women in Science, Engineering and Technology (SET) in Korea: Improving Retention and Building Capacity. *International Journal of Gender, Science and Technology, 2 (2)*, 235-248.

[19] Kurup, A., Maithreyi, R., Kantharaju, B., and Godbole, R. (prepublication). *Trained Scientific Women Power: How Much are We Losing and Why*. Bangalore: Indian Academy of Science.

[20] European Commission. (2003). *Vademecum: Gender Mainstreaming in the 6th Framework Programme– Reference Guide for Scientific Officers/Project Officers.* Brussels: Directorate-General for Research; European Commission. (2001). *Gender in Research: Quality of Life and Management of Living Resources.* Brussels: Directorate-General for Research; European Commission for Community Research. (2004). *Gender and Excellence in the Making.* Brussels: Directorate-General for Research.

[21] European Commission, Science in Society, Policy Initiatives, Gender and Research http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1297&lang=1

[22] Yellow Window Management Consultants. (2009). *Toolkit: Gender in EU-Funded Research.* Brussels: Directorate-General for Research; GenSET (2010). Recommendations for Action on the Gender Dimension in Science. Consensus Report. London: Portia. http://www.genderinscience.org/downloads/genSET_Consensus_Report_Recommendations_for_Action_on_the_Gender_Dimension_in_Science.pdf; Stanford Gendered

organizations that requires grantees to address gender analysis in grant applications for all fields, although several European countries also include this as part of their national science policies.

Policies requiring researchers to integrate gender analysis into research are more common in health research organizations. The leader in this area is Canada. In 2009, Canada passed the Health Portfolio Sex and Gender-Based Analysis Policy (SGBA) to "develop, implement, and evaluate the Health Portfolio's research, programmes, and policies to address the different needs of men and women, boys and girls." In the same year, the Canadian Institutes of Health Research issued a guide for researchers and reviewers, *Gender and sex-based analysis in health research*.[23] The World Health Organization (WHO) also mainstreams gender analysis into all "research, policies, programmes, projects, and initiatives".[24] In Europe, Sweden's Karolinska Institute and Germany's Charité Universitätsmedizin have both created centres for gender medicine that promote sex and gender analysis in basic and clinical health research.[25]

Further research is needed to compare and contrast international, national, and institutional policies on mainstreaming gender analysis into S&T research.

C. S&T EDUCATION AND EMPLOYMENT

Acquiring science and technology skills can open up a broad range of employment opportunities for women, both as highly-skilled professionals and as technicians. Girls and women, however, remain underrepresented both in the fields of study that lead to such jobs, and in S&T employment.

1. The current situation

a. Primary and secondary education

Published in 2007, UNESCO's *Science, technology and gender: an international report* provides one of the most comprehensive reviews of gender issues in science, technology, math, and engineering education. This report highlights that:

- Girls do not pursue science and technical studies at the same rate as boys, though there is variation by subject area and by country. In both developed and developing countries, parents' attitudes toward boys' and girls' abilities may be an important factor in helping to explain girls' lower rates of science and technology participation.
- There are few differences between girls and boys on standardized measures of math and science achievement. International tests show some variation by country, grade level, subject area, and specific skill, but, overall, long-assumed gaps in math ability favouring

Innovations in Science, Medicine, and Engineering Project, 2009-13, http://genderedinnovations.stanford.edu/ User id: gender; password: analysis.

[23] Spitzer, D. (2010). *Canadian Institutes of Health Research, Gender and Sex-Based Analysis in Health Research: A Guide for CIHR Researchers and Reviewers*, http://www.cihr-irsc.gc.ca/e/32019.html;

[24] World Health Organization. (2002). *Integrating Gender Perspectives in the Work of WHO*. Geneva: WHO; WHO (2002). *Gender Analysis in Health: A Review of Selected Tools.* Geneva: WHO.

[25] European Women's Health Network. (2001). *Gender-Based Analysis in Public Health Research, Policy and Practice: Documentation of the International Workshop in Berlin.* Berlin: Berlin Centre for Public Health; Haafkens, J. & Klinge, I. (2007). *Promoting Attention to the Gender Dimension in Health Research: Experiences from Three Centers of Excellence in the EU.* Universiteit Maastricht: Centre for Gender and Diversity & Care and Public Health Research Institute.

boys are narrow, if not negligible. Regional studies, moreover, show that math scores favour girls in some countries.[26]

- Science pedagogy and curricula may help to explain ongoing gender disparities in S&T interest and self-concept. Teaching strategies and materials may be consistently biased towards certain types of skills, roles, experiences, and applications that are closely linked to gender, the net result being that science is more accessible to boys than to girls.
- The international community has committed to gender equality at all levels of education by 2015.[27] Equality in S&T fields will be a particular challenge, and achieving it depends on targeted national policies directed at multiple levels: family contexts, school resources, local communities, and so on. Socioeconomics can play a major role in gender disparities; analysis of S&T outcomes by gender cannot take place apart from an analysis of household wealth and regional economies.

b. Tertiary education

Globally, in tertiary education, the median shares of female students were 41 per cent in the natural sciences and 21 per cent in engineering in 2007.[28] Many of the S&T-related questions and issues that emerge at the primary and secondary schooling levels have analogs in tertiary education. The 2007 and 2010 UNESCO reports summarize a large amount of data on the participation of women in science, math, technology, and engineering fields at the tertiary level. These data indicate:

- In the aggregate, science, engineering, and technology fields are predominantly male in the majority of countries, at every stage of higher education. However, trends are qualified by a lack of sex-disaggregated data in many countries, particularly those in the developing world.[29]
- Across all academic fields, trends are positive in terms of gender parity among graduates at tertiary first-degree levels, if not in favour of women. Within science and engineering (S&E) fields, however, the picture is different. While there are variations between countries, ranging from less than 0.5 per cent of women among S&E graduates in Samoa to 70 per cent in Sierra Leone, in the large majority of countries analyzed, women comprise less than 45 per cent. This pattern continues at the second and third degree levels. In a handful of countries, including Qatar, Cyprus, and Sierra Leone, women comprise the majority of first-degree S&E graduates.[30]

[26] Else-Quest, N., Hyde, J., & Linn, M. (2010). Cross-National Patterns of Gender Differences in Mathematics: A Meta-Analysis. *Psychological Bulletin, 136 (1)*, 103-127.

[27] United Nations. (2005). *The Millennium Development Goals Report*. New York: United Nations Publications.

[28] UNESCO. (2010). *Education for All, Global Monitoring Report: Reaching the Marginalized.* Paris: UNESCO Publishing. See Annex, Table 9B, 380-387.

[29] UNESCO. (2010). *Education for All, Global Monitoring Report: Reaching the Marginalized.* Paris: UNESCO Publishing. See Annex, Table 9B.

[30] UNESCO. (2007). *Science, Technology, and Gender: An International Report.* Paris: UNESCO Publishing. See Ch. 2, Table 2.1.

Some of the highest-volume S&E degree-producing countries are absent from the S&E data reported by UNESCO, including China (see textbox) and India.[31] However, recent data collection initiatives in India suggest that trends are similar. Between 2000 and 2010, women earned 34 per cent of all Ph.D. degrees awarded in India, but only 29 per cent of degrees in technical fields (defined as the natural sciences, agriculture, medicine, and engineering).[32] As in many countries, attrition was notable throughout the academic and professional pipeline. In 2010, for example, Indian women earned 32 per cent of all first-level degrees and 20 per cent of all third-level degrees in physics, but were only 11 per cent of professionally-employed physicists.[33]

China: Drop in physics majors

During much of the 1970s, women constituted over a third of tertiary first-degree level physics students at two of China's top universities—Beijing (42 per cent) and Nanjing (37 per cent). By 1999, women physics majors at these universities stood at only 9 per cent.

Why? The reasons are not well known. Some suggest that, in the earlier years, the government assigned women with high university entrance exams to physics in efforts to assert their equality in China's new society. Others note that the drop in numbers coincided with the opening up of China's economy to the West and a new emphasis on women's role in the family. More research is needed to understand and reverse this trend.*

*Yang J. (2002). China Debates Big Drop in Women Physics Majors. *Science* 295/5553, 263.

It is important to note that within S&T, certain fields of study attract women more than others. In the countries for which data are available, women's participation is high overall in biology, oceanography, earth, and agricultural sciences, and in environmental and biomedical engineering. For example, in the United States of America , women received 36 per cent of environmental engineering doctorates in 2008 – less than parity, but closer than in any other engineering field.[34] Fewer women are found in the physical sciences or in mechanical and electrical engineering. In Europe, for example, women make up 56 per cent of Ph.D.s in the life sciences but only 18 per cent in computer science, and in Japan women's numbers are high in agricultural science but low in physics and chemistry. In the Republic of Korea, women's participation is high in medicine and other life sciences but low in the physical sciences and math. Sex-disaggregated data of this sort are however rare, and should be collected more broadly and consistently.

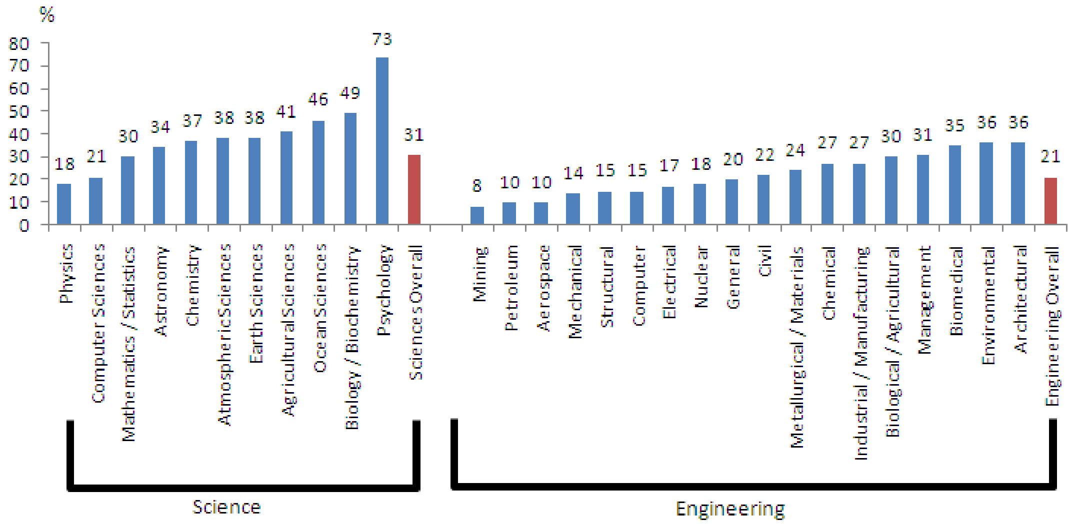
[31] Gereffi, G., Wadhwa, V., Rissing, B., & Ong, R. (2008). Getting the Numbers Right: International Engineering Education in the United States, China, and India. *Journal of Engineering Education, 97*, 13-25; Bound, J., Turner, S., & Walsh, P. (2009). Internationalization of U.S. Doctorate Education. In Freeman, R., & Goroff, D. (Eds.), *Science and Engineering Careers in the United States: An Analysis of Markets and Employment* (pp. 59-97). Chicago: University of Chicago Press.

[32] Kurup, A. & Arora, J. 2010. *Trends in Higher Education: Creation and Analysis of Database of PhDs.* Bangalore: NIAS Publications. http://eprints.nias.res.in:8081/134/1/trends_report_2010.pdf

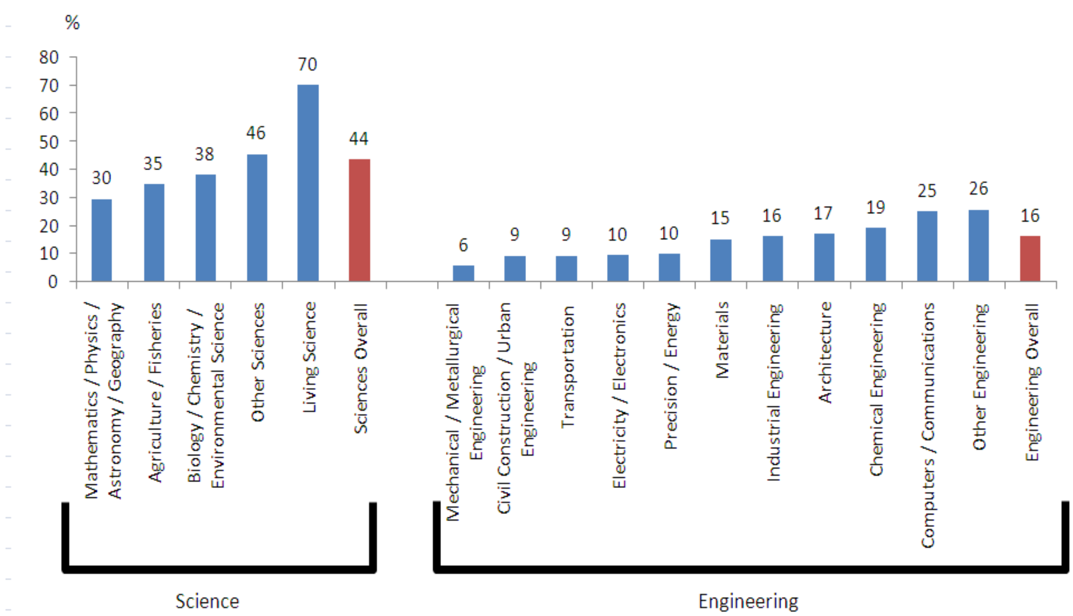
[33] Kurup, A., Maithreyi, R., Kantharaju, B., and Godbole, R. (prepublication). *Trained Scientific Women Power: How Much are We Losing and Why*. Bangalore: Indian Academy of Science. http://www.ias.ac.in/womeninscience/surveyreport_web.pdf

[34] Gibbons, M. (2008). Engineering by the Numbers. American Society for Engineering Education. http://www.asee.org/publications/profiles/upload/2008ProfileEng.pdf

Women's share of doctoral degrees in science (2007)[35] and engineering (2008)[36], United States of America :



Women's share of bachelor's, master's, and doctoral degrees combined among permanent employees in R&D (2007)[37], Republic of Korea:



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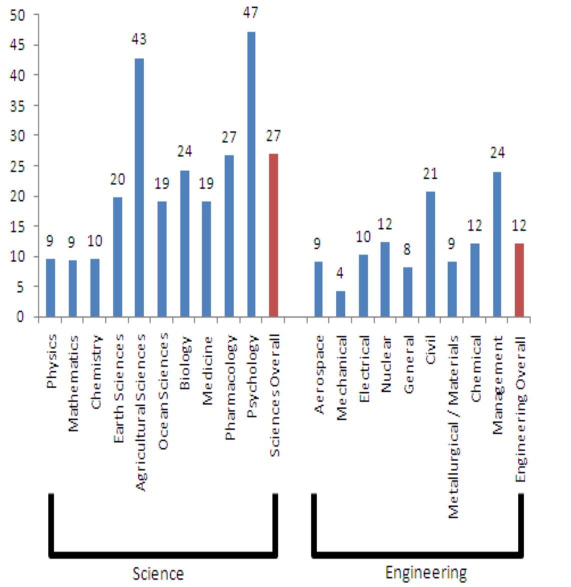
[35] NSF. (2007). *Science and Engineering Doctoral Degrees Awarded to Women, by Field: 1998–2007.* http://www.nsf.gov/statistics/wmpd/pdf/tabf-2.pdf

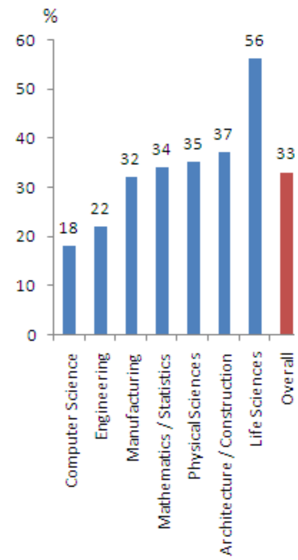
[36] American Society of Engineering Education. (2008). *Engineering by the Numbers.* http://www.asee.org/publications/profiles/upload/2008ProfileEng.pdf

[37] In the Republic of Korea, 'living sciences' refers to family and consumer sciences, and should not be mistaken for life sciences. Lee, K. (2010). Women in Science, Engineering, and Technology (SET) in Korea: Improving Retention and Building Capacity. *International Journal of Gender, Science, and Technology, 2 (2)*, 235-248; Korean National Institute for Supporting Women in Science and Technology (NISWIST). (2009). *Report on Women in Science and Engineering*. Seoul: Ministry of Education, Science, and Technology.

Women's share of doctoral degrees in science and engineering (2009)[116], Japan:



Women's share of science and engineering degrees by broad field (2006)[117], European Union:



c. Employment

While there is no global figure reporting the share of women in S&T research, the Organisation for Economic Cooperation and Development (OECD) chart on 33 countries below illustrates the widespread underrepresentation of women as researchers in the natural sciences and engineering.[38] The OECD reports that, overall, 27 per cent of researchers in the countries analyzed are women. Argentina has the highest proportion of women researchers, at 51 per cent. Women are 34 per cent of researchers in Europe overall, but their representation differs geographically. Women are better represented in Eastern Europe (40 per cent). Women make up only 14 per cent of researchers in Japan.[39]

Several countries with significant numbers of researchers, including the United States of America, Brazil, China, and India, are not included in the OECD data. According to the United States National Science Foundation's definitions, 41 per cent of natural science and engineering researchers in the United States of America are women.[40] Another common measure indicates that women in the United States of America make up 30 per cent of professors of science and

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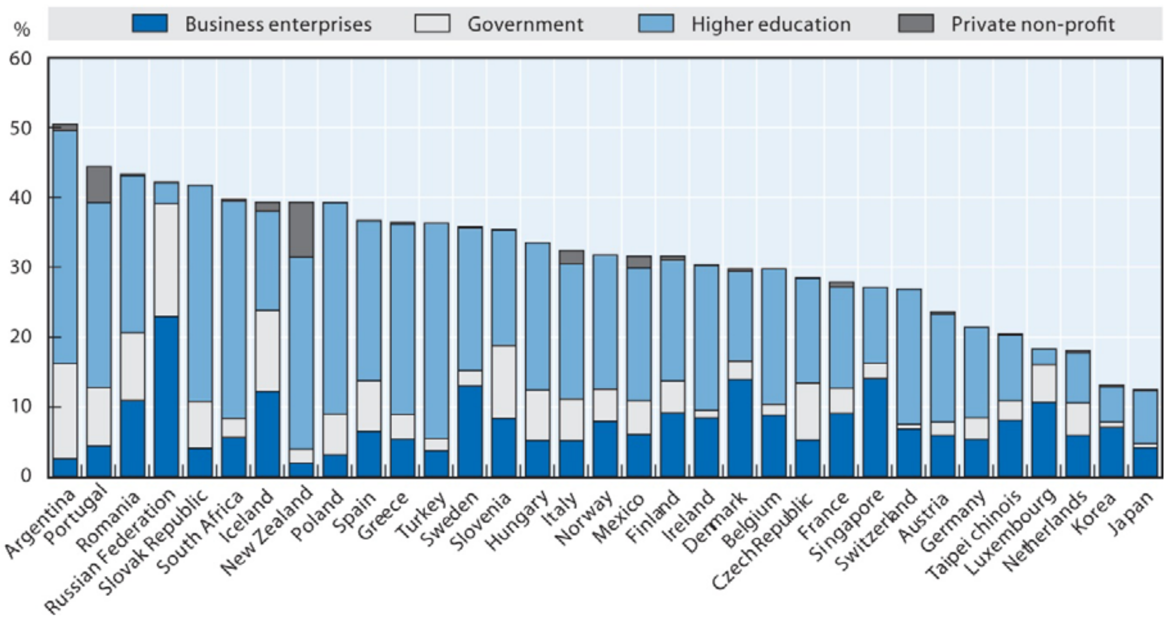
[38] Organization for Economic Cooperation and Development. (2008). *Science, Technology, and Industry Outlook.* Paris: OECD Publications, see Figure 1.36.

[39] OECD data was sorted by region in accordance with the United Nations Geoscheme. See United Nations Statistics Division. (2010). Composition of Macro-Geographical (Continental) Regions, Geographical Sub-Regions, and Selected Economic and Other Groupings. http://millenniumindicators.un.org/unsd/methods/m49/m49regin.htm

[40] NSF. (2010). Scientists and Engineers Statistical Data System (SESTAT). http://www.nsf.gov/statistics/sestat/ The NSF defines researchers as persons with Bachelor's degrees or higher who spend at least 10 per cent of their working hours generating scientific knowledge for theoretical or practical purposes. See NSF. (2008). *National Survey of College Graduates 2008*. United States Department of Commerce Economics and Statistics Administration. http://www.nsf.gov/statistics/srvygrads/surveys/srvygrads_2008.pdf

Women researchers by sector of employment, 2006

As a % of total researchers



http://dx.doi.org/10.1787/451463482377

Notes: 2005 instead of 2006 for Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, and South Africa; 2004 for Austria, and Switzerland; 2003 for Mexico; 2001 for New Zealand.

engineering.[41] Brazil reports 28 per cent female researchers in the natural sciences and 18 per cent in engineering.[42] China reports that women constitute 40 per cent of scientific and technological personnel and a third of the senior leadership in those fields (it remains unclear whether these figures include the social sciences in addition to the natural sciences).[43] Comprehensive figures for India are not available.[44] However, a localized study in the state of Kerala found that 37 per cent of natural scientists research in institutes and universities were women.[45] Kerala's literacy rate gap between men and women is much smaller than in India as a

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[41] NSF. (2006). *Women, Minorities, and Persons with Disabilities in Science and Engineering*. See Table H-22: Science and Engineering Doctorate Holders Employed in Universities and Four-Year Colleges, by Broad Occupation, Sex, Years since Doctorate, and Faculty Rank.

[42] Silva, R. (2008). Engineer Women Take Top Level Management in Brazil. Proceedings of the 2008 Intra-American Juridical Committee (IAJC)-Institute for Advanced Medical Education (IAME) International Conference, Paper 233.

[43] General Assembly and International Conference of the Organization for Women in Science for the Developing World (2010), remarks by China's Vice President Xi Jinping. http://english.cas.cn/accessory/twows4th/events/201006/t20100628_55814.html; Personal communication, Wen Ke, Associate Professor, Institute of Policy and Management, Chinese Academy of Sciences, 25 August 2010.

[44] Kurup, A., Maithreyi, R., Kantharaju, B., & Godbole, R. (prepublication). *Trained Scientific Women Power: How Much are We Losing and Why*. Bangalore: Indian Academy of Science.

[45] Miller, B., Sooryamoorthy, R., Anderson, M, Palackal, A., & Schrum, W. (2006). Gender and Science in Developing Areas: Has the Internet Reduced Inequality? *Social Science Quarterly, 87 (3)*, 679-689; researchers were formal employees of universities and institutes as described in Duque, R., Ynalvez, M., Sooryamoorthy, R., Mbatia, P., Dzorgbo, D., & Shrum, W. (2005). The 'Collaboration Paradox': Scientific Productivity, the Internet, and Problems of Research in Developing Areas. *Social Studies of Science, 35 (5)*, 755-785.

whole, suggesting that Kerala's percentage of female researchers is likely higher than the percentage in India overall.

Inequalities between men and women researchers are greater than suggested by these statistics. There seems to be an inverse relationship between representation of women and research spending per capita, meaning that where science is well funded and prestigious, the share of women working in S&T tends to be smaller. Countries that spend the most on research in the natural sciences (more than $150,000 per researcher per year) have few women researchers (21 per cent on average). For example, Japan spends $149,000 per researcher per year and the Netherlands $197,000; these countries have 12 per cent and 18 per cent female researchers, respectively. Countries that spend the least on research (less than $50,000) have many women researchers (40 per cent on average). For example, Argentina spends $39,000 annually per researcher and has 51 per cent women; Poland spends $30,000 and has 39 per cent. A few countries are exceptions to this trend. For example, Italy spends a relatively large amount ($142,000) and has relatively many female researchers (32 per cent).[46]

i. Career progression and decision-making

Women generally comprise a minority of scientists, technologists, and engineers across sectors and countries. Women are also underrepresented in positions of S&T leadership—in senior professorships, research projects, institutional management, granting organizations, learned societies, and among journal editors.[47] In the United States of America , for example, 41 per cent of assistant professors in the biological/life sciences are women, as compared with 21 per cent of full professors. In computer science, 21 per cent of assistant professors are women, as compared with 11 per cent of full professors. In engineering, 19 per cent of assistant professors are women, as compared with 4 per cent of full professors.[48] As of 2004, approximately 95 per cent of department chairs in engineering, mathematics, and physical sciences departments at major United States of America research institutions were men.[49]

The declining representation of women at successive stages of scientific and technological careers is evident around the globe. The multinational InterAcademy Council (IAC), for example, reported in 2006 that women "form a small minority (typically less than 5 per cent)" of the membership of leading national science academies.[50] According to the European Commission's *She figures 2009*, although women comprise more than one-third of doctoral students in science and engineering, they comprise 33 per cent of Grade C academic staff, 22 per cent of Grade B staff, and 11 per cent of Grade A staff (the highest post at which

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[46] All values in 2005 US dollars, converted from local currency at World Bank exchange rates averaged over FY 2005, corrected for purchasing-power parity. Data sourced from UNESCO (2005). Data Centre, Public Reports, Science and Technology, Table 3: *Researchers by Sex (Full-Time Equivalent and Head Count)* and Table 11: *Gross Domestic Expenditure on Research and Development*; Data sourced from OECD. (2010). OECD Online Statistics Database. http://stats.oecd.org/index.aspx?r=584249

[47] European Commission. (2009). *She Figures*. Luxembourg: Office for Official Publications of the European Communities.

[48] NSF. (2006). *Survey of Doctorate Recipients.* NSF Division of Science Resource Statistics. http://www.nsf.gov/statistics/wmpd/employ.cfm. See Table H-22.

[49] Niemeier, D., & Gonzalez, C. (2004). Breaking Into the Guildmasters' Club: What We Know About Women Science and Engineering Department Chairs at AAU Universities. *National Women's Studies Association Journal, 16*, 157-171.

[50] InterAcademy Council. (2006). *Women for Science: An Advisory Report*. Publications of the IAC Secretariat, June.

research is conducted).[51] The percentage of women in grade A positions varies by field, with engineering and technology at the lowest (7 per cent in the EU-27, as compared with 13 per cent in the natural sciences, and 17 per cent in the medical sciences overall). The low representation of women in engineering and technology grade A positions is particularly evident in Denmark, Cyprus, Lithuania, and Malta.

It is not simply time lag or 'generational effect' that accounts for women's underrepresentation at senior levels.[52] A recent report by the National Academies notes that gender differences in the relative likelihood of moving up academic 'ladders' may start early, i.e., the proportion of women applicants to academic jobs in S&E fields is lower than is the proportion of women doctorates in those fields. Moreover, the authors write, "in every field, women were underrepresented among candidates for tenure relative to the number of women assistant professors. Most strikingly, women were most likely to be underrepresented in the fields in which they accounted for the largest share of the faculty–biology and chemistry".[53]

ii. Entrepreneurship

Entrepreneurship drives, and is driven by, innovation in S&T. Patenting rates are one possible measure of entrepreneurship. In general, women are a minority of patent holders; women are less than 5 per cent of patent authors in Sweden, for example.[54] Women across Europe are underrepresented as holders of patents, even relative to their representation in patent-generating academic fields. Rates of patenting also lag behind women's publication rates (see chart below). The trend holds outside of Europe as well. In the United States of America , women made up 30 per cent of IT workers and researchers in 2005, but only 5 per cent of patent authors.[55] A 1992 study at India's Counsel of Scientific and Industrial Research (CSIR) showed that women (who made up 9 per cent of all researchers at CSIR) were only 57 per cent as likely as men to obtain patents.[56] Women are issued patents at lower rates than men in the three main spheres of technological employment: academia (which produces relatively few patents), private industry (which produces many), and government.[57]

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[51] European Commission. (2009). *She Figures*. Luxembourg: Office for Official Publications of the European Communities, 67.

[52] ETAN Expert Working Group. (2000). *Science Policies in the European Union.* Brussels: European Commission, 13. See Figure 2.5.

[53] National Academies. (2009). *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty*. Washington, D.C.: National Academies Press, 9; European Commission. (2009). *She Figures*. Luxembourg: Office for Official Publications of the European Communities, 69.

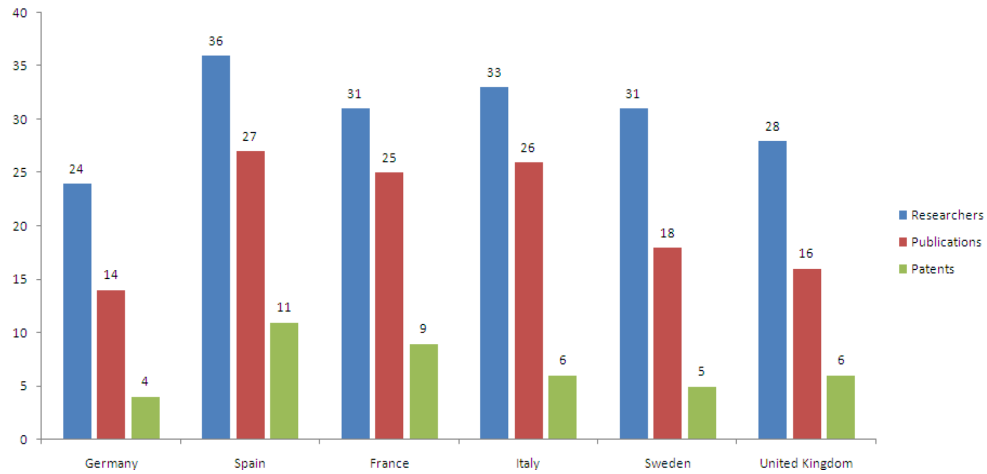
[54] Nyberg, A. (2009). Making Ideas Matter: Gender, Technology, and Women's Invention. Doctoral Thesis, Luleå University of Technology, Department of Human Work Sciences. http://www.ltu.se/polopoly_fs/1.17258!avhandling%20ac%20nyberg.pdf

[55] Rosser, S. (2009). The Gender Gap in Patenting: Is Technology Transfer A Feminist Issue? *National Women's Studies Association Journal, 21 (2)*, 65-84.

[56] Lemoine, W. (1992). The Frequency Distribution of Research Papers and Patents According to Sex: The Case of CSIR—India. *Scientometics, 24 (3)*, 449-469.

[57] Mauleón, E., & Bordons, M. (2005). Male and Female Involvement in Patenting Activity in Spain. *Scientometrics*, *83 (3)*, 605-621.

Per cent women as researchers, authors of peer-reviewed publications, and authors of patents (2005)[58]



Various programmes have been established to encourage women entrepreneurs. One successful Swedish initiative provided mentoring and legal advice to public healthcare workers, many of whom were female. The project produced several commercially-successful products, such as undergarments to improve the mobility of patients using catheters.[59] Another initiative seeks to highlight the achievements of women inventors and entrepreneurs in efforts to draw more women into the field. In 2009, the World Intellectual Property Organization (WIPO) recognized women entrepreneurs from fifteen different countries.[60] Other initiatives seek to increase the availability of venture capital to qualified women.[61]

2. Explanatory factors: Gender disparities in education and employment

Why are there so few women in science and engineering? Many of the reasons for women's underrepresention are similar for S&T education and employment. These are addressed below.

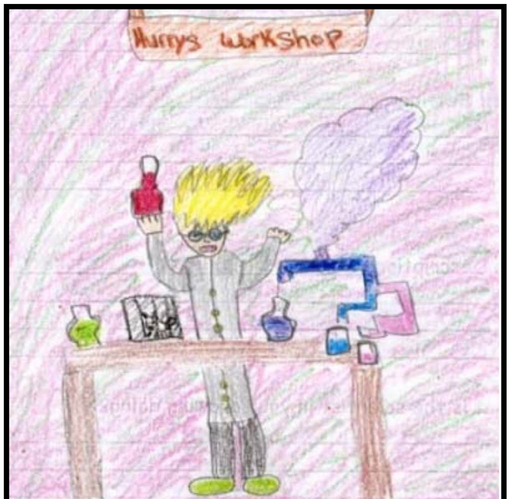
a. Stereotypes and cultural environments

In many countries, engineering and the physical sciences – as communities of practice – continue to be seen, and experienced, as 'masculine'.[62] These gender stereotypes are sometimes

[58] Naldi, F., Luzi, D., Valente, A., & Parenti, I. (2005). Scientific and Technological Performance by Gender. In Moed, H., Glänzel, W., & Schmoch, U. (Eds.), *Handbook of Quantitative Science and Technology Research* (pp. 299-314). Netherlands: Springer.
[59] Nählinder, J. (2010). Where are All the Female Innovators? Nurses as Innovators in a Public Sector Innovation Project. *Journal of Technology Management and Innovation, 5 (1)*, 13-29.
[60] World Intellectual Property Organization. (2010). Women Inventors Awarded a WIPO Medal or other Distinction: Index by Date of Award. http://www.wipo.int/ip-outreach/en/awards/women/year.html
[61] Ranga, M., & Etzkowitz, H. (2010). Athena in the World of Techne: The Gender Dimensions of Technology, Innovation, and Entrepreneurship. *Journal of Technology Management and Innovation, 5 (1)*, 1-12.
[62] Faulkner, W. (2006). Genders In / Of Engineering: A Research Report. London: Institution of Civil Engineers Economic and Social Research Council. http://extra.shu.ac.uk/nrc/section_2/publications/reports/Faulkner_Genders_in_Engineering_Report.pdf

unconscious, and may prevail even in people who support gender equality in science and technology. Such stereotypes may affect girls' and women's performance, self-assessment, and interest in science and engineering.

Western-style science has been seen as masculine on the grounds that it is logical and objective—traits associated culturally with Western-style masculinity.[63] Science has also been defined in terms of what it is *not*. Science is popularly conceived as free of emotion and sentimentality—traits associated with femininity.[64]



"Harry's workshop," depicting Harry actively experimenting in his lab. Note the Einstein hair.

Fralick, B., Kearn, J., Thompson, S., Lyons, J. (2008). How Middle Schoolers Draw Engineers and Scientists. *Journal of Science Education and Technology*, 18, 60-73.

These associations permeate research communities and influence popular perceptions of S&T. Television shows, advertisements, video games, and toys send the message that S&T is for boys. Masculine stereotypes of science and engineering are so pervasive that when asked to draw a 'scientist', the majority of school children in the United States of America (61 per cent) draw a male (see image).

Scientific disciplines have distinctive cultures that greatly influence who is attracted to a particular field. Low female participation in physics has led to questions concerning what about physics deters women. Astrophysicist C. Megan Urry characterizes the culture of physics as one that rewards people who are boastful, arrogant, and self-assured. It is not necessarily the best ideas that win out, but the ones more tenaciously defended. She observes that women, raised to be polite and deferential, do not flourish in this setting.[65] Most recently, a study highlighted the role of actual objects in undergraduate science environments in deterring women's participation. Perceived as highly masculine, stereotypical objects such as Star Trek posters, computer parts, and comics diminish women's sense of 'ambient belonging' in a given scientific community, and lead to lower levels of interest in joining this community.[66]

As science and engineering change, perceptions of these fields need to keep pace. Modern engineers, for example, do not require 'brawn' as they once did when engineering was grounded in the heavy manual labour of the shop floor. Today they need 'brain'—a combination of technical and interpersonal skills. Several organizations are attempting to remake the image of

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[63] Keller, E. (2004). Gender and Science. In Harding, S., & Hintikka, M. (Eds.) *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science* (Chapter 3). Netherlands: Springer Publishing.

[64] Schiebinger, L. (1989). *The Mind Has No Sex? Women in the Origins of Modern Science*. Cambridge, Mass.: Harvard University Press.

[65] Urry, C. (2008). Are Photons Gendered? Women in Physics and Astronomy. In Schiebinger, L. (Ed.), *Gendered Innovations in Science and Engineering* (pp. 150-164). Stanford: Stanford University Press.

[66] Cheryan, S., Plaut, V., Davies, P., & Steele, C. (2009). Ambient Belonging: How Stereotypical Cues Impact Gender Participation in Computer Science. *Journal of Personality and Social Psychology, 97 (6),* 1045-60.

the engineer to match the reality of contemporary engineering.[67] The International Institute of Electrical and Electronics Engineers (IEEE) has identified 'big-picture thinking' and emphasizing the potential for engineers to contribute to human welfare as essential to attracting women and underrepresented minorities to engineering.[68] The United States National Academy of Engineering has created the 'Engineer Girl' programme, which seeks to increase female enrollment by 1) providing a positive image of engineering, and 2) providing guidance to girls about how to prepare for an engineering education.[69]

There is a need to study stereotypes in S&T in developing countries. Stereotypes are specific to cultures. Women and men as groups are not homogenous—there are many forms of femininity and masculinity, and these differ by region, religion, class, national culture, and other key social factors.

b. Gender bias in hiring and promotion

Evidence shows that gender bias influences the careers of men and women scientists and engineers. Gender differences exist in grant awards, salaries, productivity, and patents; these differences are structurally driven, with the potential for cumulative and negative impacts on women's career advancement.[70] Moreover, core 'gate-keeping' mechanisms – such as letters of recommendation for employment – interact with gender in hiring practices:

- A recent study of letters of recommendation in chemistry and biochemistry suggests that letters written for male applicants have more 'standout adjectives' than do letters for female applicants. The achievements of male students are more often attributed to natural ability and talent; those of female students are more often attributed to methodical, 'grindstone' work.[71]
- Curriculum vitae presented by job applicants are evaluated more positively when a male name is attached than a female name. Both male and female evaluators are more

[67] Faulkner, W. (2006). Genders In / Of Engineering: A Research Report. London: Institution of Civil Engineers Economic and Social Research Council. http://www.ice.org.uk/downloads/Faulkner_Genders_in_Engineering_Report.pdf

[68] International Institute of Electrical and Electronics Engineers. (2008). *IEEE Women in Engineering*. New York: QMags. See also Wolffram, A., & Winker, G. (2004). Challenging Gender Stereotypes in Engineering Education, International Symposium of the Internationale Gesellschaft für Ingenieurpädagogik (IGIP), Fribourg, Switzerland, September 27-30.

[69] Roncone, K. (2005). Child's Play: Using the Internet to Learn about Science and Engineering. *Journal of the Minerals, Metals, and Materials Society, 57 (10)*, 12-15; National Academies. (2010). Turn Imagination into Reality with a Career in Engineering. http://www.engineergirl.org

[70] Waisbren, S., Bowles, H., Hasan, T., Zou, K., Emans, S., Goldberg, C., Gould, S., Levine, D., Lieberman, E., Loeken, M., Longtine, J., Nadelson, C., Patenaude, A., Quinn, D., Randolph, A., Solet, J., Ullrich, N., Walensky, R., Weitzman, P., & Christou, H. (2008). Gender Differences in Research Grant Applications and Funding Outcomes for Medical School Faculty. *Journal of Women's Health, 17 (2)*, 207-214; Ley, T., & Hamilton, B. (2008). The Gender Gap in NIH Grant Applications. *Science, 322*, 1472-1474; Umbach, P. (2007). Gender Equity in the Academic Labour Market: An Analysis of Academic Disciplines. *Research in Higher Education, 48 (2)*, 169-192; Xie, Y., & Shauman, K. (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, Mass: Harvard University Press; Ding, W., Murray, F., & Stuart, T. (2006). Gender Differences in Patenting in the Academic Life Sciences. *Science, 313*, 665-667.

[71] Schmader, T., Whitehead, J., & Wysocki, V. (2007). A Linguistic Comparison of Letters of Recommendation for Male and Female Chemistry and Biochemistry Job Applicants. *Sex Roles, 57,* 509-514.

likely to approve an application with a male name than an otherwise-identical application with a female name.[72]

- A study of postdoctoral fellowship applications showed that female applicants were judged less scientifically competent than male applicants who had comparable bodies of published work. [73]

Evaluation practices may also be biased. At corporate research and development laboratories, measures of performance and perceptions of competence are often unconsciously modeled on masculine qualities of leadership, leaving female scientists at a disadvantage.[74] In a study of high-tech companies in the Silicon Valley, women managers received far less favourable evaluations of technical competence than did male managers, even though they had the same level of competence.[75] Characteristics associated with conventional styles of leadership are viewed as incongruent with female gender roles. This means that women may face prejudice in leadership evaluations.[76] Moreover, women who display assertiveness may be perceived as competent, but unpleasant.[77] Similarly, women may be penalized more than men for initiating salary negotiations, especially when the evaluator is male.[78] All these factors disadvantage women who seek leadership roles in science and technology.

c. Women's disproportionate domestic and care work

A complex problem in differential career pathways for women and men scientists and engineers is the gendered division of labour in households and families, and the disproportionate share of such labour women assume. Cross-culturally, women generally take on the majority of childcare and household labour. Recent research confirms that 'divided and unequal' household configurations disadvantage tenured and tenure-track women scientists at major research universities in the United States of America as well as women in other fields. Women perform twice as much core housework (cooking and grocery shopping, laundry, and housecleaning) and 1.5 times as much childcare as do their male colleagues, underscoring an important difference in the way men and women scientists must apportion their time.[79] It comes as little surprise, perhaps, that women who achieve tenure are less likely to have children than are men who achieve tenure, across all academic disciplines in the United States of America.[80]

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[72] Steinpreis, R., Ritzke, D., & Anders, K. (1999). The Impact of Gender on the Review of the Curricula Vitae of Job Applicants and Tenure Candidates: A National Empirical Study. *Sex Roles, 41*, 509-528.

[73] Wenneras, C., & Wold, A. (1997). Nepotism and Sexism in Peer Review. *Nature, 387*, 341-343.

[74] Smith, D., DiTomaso, N., Farris, G., & Cordero, R. (2001). Favouritism, Bias, and Error in Performance Ratings of Scientists and Engineers: The Effects of Power, Status, and Numbers. *Sex Roles, 45*, 337-358.

[75] Simard, C., Henderson, A., Gilmartin, S., Schiebinger, L., & Whitney, T. (2008). *Climbing the Technical Ladder: Obstacles and Solutions for Mid-Level Women in Technology*. Anita Borg Institute for Women and Technology and the Michelle R. Clayman Institute for Gender Research, Stanford University.

[76] Eagly, A., & Karau, S. (2002). Role Congruity Theory of Prejudice towards Female Leaders. *Psychological Review, 109,* 573-598; Eagly, A., & Carli, L. (2007). *Through the Labyrinth: The Truth About How Women Become Leaders.* Boston: Harvard Business School Press.

[77] Rudman, L., & Glick, P. (2001). Prescriptive Gender Stereotypes and Backlash toward Agentic Women. *Journal of Social Issues, 57 (4),* 743-762.

[78] Bowles, H., Babcock, L., & Lai, L. (2007). Social Incentives for Gender Differences in the Propensity to Initiate Negotiations: Sometimes it does Hurt to Ask. *Organizational Behavior and Human Decision Processes, 103,* 84-103.

[79] Schiebinger, L., & Gilmartin, S. (2010). Housework is an Academic Issue. *Academe, 96,* 39-44.

[80] Mason, M., & Goulden, M. (2002). Do Babies Matter? The Effect of Family Formation on the Lifelong Careers of Academic Men and Women. *Academe, 88 (6),* 21-27.

Not only does evidence suggest cognitive bias against mothers in the hiring process (data are not specific to S&T fields)[81], but gender roles and their associated obligations, commitments, and expectations impede women's participation and advancement in scientific careers. As UNESCO states, "many women are forced to give up work or change to a part-time job (and there are few of those within S&T) unless a way can be found to combine their caring responsibilities with their current job".[82] Implicit in this statement is the reality that many male partners contribute less than an equal share to domestic life, leaving women with disproportionately large burdens.

Namrata Gupta and Arun Sharma describe how Indian women scientists grapple with the 'dual burden' of career and home. Despite this, married women usually have an advantage over single women in the S&T workplace, since single Indian women face significant social and professional barriers to collaborating with male colleagues.[83] By contrast, single and childless women scientists in the United States of America and Germany tend to have advantages in terms of career advancement.[84]

3. Solutions: Increasing girls' and women's participation in education and employment

a. Making S&T education female friendly

There are several approaches to overcome gender disparities in S&T education. The first seeks to make traditionally male environments more female friendly. Recent innovations in S&T education benefit not only girls but also improve the quality of education in general.[85] These include:

- Emphasizing how S&T can effect positive social change related to health, environment, and safety.[86] For example, an introductory chemistry course might highlight the synthesis of steroids, which make birth control pills possible—a matter of special concern to women.[87]
- Implementing hands-on coursework. Prevailing gender roles mean that many male students arrive at school with practical S&T experience, such as repairing cars, using chemistry sets, etc.[88] Hands-on coursework has been shown to bolster skills and

[81] Correll, S., Benard, S., & Paik, I. (2007). Getting a Job: Is there a Motherhood Penalty? *American Journal of Sociology, 112 (5)*, 1297-1338.
[82] UNESCO. (2007). *Science, Technology and Gender: An International Report*. Paris: UNESCO, 110.
[83] Gupta, N., & Sharma, A. (2002). Women Academic Scientists in India. *Social Studies of Science, 32,* 901-915.
[84] Ginther, D., & Kahn, S. (2009). Does Science Promote Women? Evidence from Academia, 1973—2001. In Freeman, R., & Goroff, D. (Eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment* (Chapter 5). Chicago: University of Chicago Press; Mason, M., Goulden, M., & Wolfinger, N. (2008). Babies Matter: Pushing the Gender Equity Revolution Forward. In Bracken, S., Allen, J., & Dean, D. (Eds.), *The Balancing Act: Gendered Perspectives in Faculty Roles and Work Lives* (Section I). Sterling, Virginia: Stylus Publishing.
[85] Margolis, J., & Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing.* Cambridge, Mass.: MIT Press.
[86] Mayberry, M. (1998). Reproductive and Resistant Pedagogies: The Comparative Roles of Collaborative Learning and Feminist Pedagogy in Science Education. *Journal of Research in Science Teaching, 35 (4),* 443-459.
[87] Marks, L. (2001). *Sexual Chemistry: A History of the Contraceptive Pill*. New Haven: Yale University Press.
[88] Foor, C., Walden, S., & Trytten, D. (2007). "I Wish that I Belonged More in this Whole Engineering Group": Achieving Individual Diversity. *Journal of Engineering Education*, April, 103-115.

confidence in both male and female students without such experience, and to close achievement gaps between young men and women.[89]

- Creating collaborative learning environments. Such environments have been shown to be more attractive to women than highly-regimented classrooms.[90]
- Creating an inviting classroom. The physical layout of a classroom can be used to create a more inclusive environment—from the choice of posters displayed on the walls to seating arrangements.[91]
- Creating grading policies that provide students with insight into their standings relative to other class members. Female students tend to underestimate their class standings relative to male students— that is, a male student with a given grade will typically perceive himself to be higher in class standing than a female student with an identical grade.[92] Transparent grading can bolster female students' confidence.

One example is that of the Government of the United Republic of Tanzania, which addressed its gender gap in science and mathematics through two five-year initiatives: the Primary Education Development Program (PEDP) and Secondary Education Development Program (SEDP).[93] These programmes have implemented strategies such as annual science camps for girls and female-friendly science and mathematics course materials.[94] Concrete results have been produced: in secondary education, women's pass rates on standardized tests increased substantially between 1996 and 2000 – 38 per cent in mathematics, 17 per cent in physics, and 15 per cent in chemistry. Much remains to be done, however, especially at the tertiary level where women comprise only 3 per cent of students earning S&T degrees.[95]

b. Changing research priorities, goals, and outcomes to increase women's participation

Another approach to overcoming gender disparities in S&T education is to analyze what attracts women to particular fields. Educational and career choices are shaped by a range of factors, including students' performance, enjoyment, and interest in given subject matters. Fields such as the life sciences, for instance biology or environmental science, should be studied to

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[89] Burkam, D., Lee, V., & Smerdon, B. (1997). Gender and Science Learning in Early High School: Subject Matter and Laboratory Experiences. *American Educational Research Journal, 34 (2),* 297-331; Roberts, E., Kassianidou, M., & Irani, L. (2002). Encouraging Women in Computer Science. *Inroads,* June, 1-5.

[90] Faulkner, W. (2007). 'Nuts and Bolts and People': Gender-Troubled Engineering Identities. *Social Studies of Science, 37 (3),* 331-356.

[91] Cheryan, S., Plaut, V., Davies, P., & Steele, C. (2009). Ambient Belonging: How Stereotypical Cues Impact Gender Participation in Computer Science. *Journal of Personality and Social Psychology, 97 (6),* 1045-60.

[92] Barker, L., & Cohoon, J. (2009). Key Practices for Retaining Undergraduates in Computing. National Center for Women and Information Technology. http://www.ncwit.org/pdf/KeyPracticesRetainingUndergraduatesComputing_FINAL.pdf; Henwood, F. (2000). From The Women Question in Technology to the Technology Question in Feminism: Rethinking Gender Equality in IT Education. *European Journal of Women's Studies, 7,* 209-277.

[93] Machimu, G., & Minde, J. (2010). Rural Girls' Educational Challenges in Tanzania: A Case Study of Matrilineal Society. *The Social Sciences, 5 (1),* 10-15.

[94] Mungai, J. (2004). Secondary Education Development Plan (SEDP). United Republic of Tanzania Ministry of Education and Culture Education Sector Development Programme. http://planipolis.iiep.unesco.org/upload/Tanzania%20UR/Tanzania%20UR%20Secondary%20Education%20Development%20Plan.pdf

[95] Masanja, V. (2007). Gender Disparity in Science and Mathematics Education. Mathematics Department University of Dar Es Salaam, Tanzania. http://www.hbcse.tifr.res.in/episteme/episteme-1/themes/vedianamasanja%20modified.pdf

determine what about them attracts women. Current studies suggest that women are attracted to research that directly serves human needs.[96]

An example of this is found at the University of California, Berkeley, where Professor Andrew Szeri changed the demographics of his lab in mechanical engineering, a traditionally male dominated field, from a majority male to a majority female. How did he do it? “The mathematical methods upon which I rely heavily have not changed much at all,” he wrote. “It is, rather, the goals of the projects which have”.[97] Women joined Szeri’s lab when interdisciplinary research addressed compelling social goals. Szeri’s new research aims at particular socially-relevant outcomes, such as developing female-controlled HIV protection. One of the stated goals of Szeri’s research is to assist women in cultures where they may have less power to say ‘no’ to sex or cannot rely on their partners to use condoms.

Women’s preference for socially engaged research is shown also at the Technical University in Berlin, Germany, where one math course is offered through two different master’s level engineering programmes. When this math course is offered in the programme for ‘Engineering Science,’ the students are predominately men. When this very same math course is offered in the programme for ‘Global Engineering for Solar Technology,’ many more women participate. The course is the same; the purpose of the programmes differs.[98]

Women’s participation in research often depends upon its having clear social goals. Analyzing research priorities and social outcomes should be an integral part of basic research design—and not an ‘ethical’ component considered separately (see methods of sex and gender analysis #2). Researchers should examine research priorities: How are priorities set regarding what is to be known (and not known) in the context of limited resources?[99] Further, researchers should consider who will benefit in terms of wealth and well-being, and who will not, from a particular research project.

c. Understanding women’s preferences: Interdisciplinary research

Another trend of note is that women tend to hold interdisciplinary appointments. A study at the University of California, Berkeley, in the United States of America, for example, found that 26 per cent women vs. 15 per cent men hold inter-departmental appointments. Bioengineering, one of the new interdisciplinary departments at Berkeley, has 50 per cent women on faculty.[100] A study of universities in the United Kingdom showed that women researchers engaged in interdisciplinary project more often than men across all fields (humanities, social science, and natural science).[101] This suggests that research institutions may undergo structural change as women gain equality. Established disciplines—and the prestige hierarchy among them—may change as newcomers are accommodated.

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[96] Rosser, S. (2000). *Women, Science and Society: The Crucial Union***.** New York: Teachers College Press, chap. 2; Hill, C., Corbett, C., & St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics.* Washington, D.C.: American Association of University Women Press, 23.
[97] Szeri, A. (2009). Email communication with Schiebinger, L. September 4th.
[98] Schraudner, M. (2010). Personal communication, results of study conducted at Technical University, Berlin, Germany.
[99] Harding, S. (1991). *Whose Science? Whose Knowledge.* Ithaca: Cornell University Press.
[100] National Academies. (2006). *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, D.C.: National Academics Press. See also Rhoten, D., & Pfirman, S. (2007). Women in Interdisciplinary Science: Exploring Preferences and Consequences. *Research Policy*, *36*, 56–75.
[101] Higher Education Funding Council of England (HEFCE). (1999). *Interdisciplinary Research and the Research Assessment Exercise*. London: Evaluation Associates Ltd.

d. Sensitizing researchers to gender issues

Strategies to overcome barriers to women's careers differ across nations and institutions, and are specific to local contexts. Initiatives range from benefits to support daycare and housework, flextime with regard to tenure systems or working hours, and couple hiring in addition to reevaluating how interdisciplinary research teams function, how hiring priorities are determined, how searches for qualified personnel are conducted, and the like.[102] S&T personnel need to become familiar with gender scholarship on institutional transformation. There is an urgent need to convey the findings from this body of literature to the current generation of researchers.

The question is how to train S&T researchers, both men and women. One successful North American programme, the University of Michigan's Strategies and Tactics for Recruiting to Improve Diversity and Excellence (STRIDE), took on the issue of training researchers how to avoid subtle gender bias in S&T hiring. Michigan increased its hires of women in the natural sciences and engineering from 14 per cent pre-STRIDE to 35 per cent post-STRIDE. In this programme, distinguished senior science and engineering faculty (five men and four women) were paid a stipend to learn the scholarly literature on gender bias in hiring practices. These S&T faculty then prepared a handbook that they used to teach their colleagues on hiring committees about evaluation bias and other barriers women face in academia.

The brilliance of the STRIDE programme is that these senior faculty are all regular members of departments. Because these newly trained gender experts are permanent and respected members of science and engineering faculties, knowledge concerning subtle gender bias cascades through the institution. The academic climate of opinion changes gradually as these faculty go about their day-to-day work.[103] This programme and others like it convey the many findings from gender research to S&T researchers and engage them as active participants in institutional reform.

GenSET, a project funded by European Commission (2009-2012), is another initiative that seeks to convey findings from gender scholarship to S&T researchers.[104] Through a series of workshops, this project brings together scientists, administrators, and gender experts from across Europe to produce practical guidelines to help European science institutions increase women's participation. The recommendations from GenSET workshops focus on four areas: science

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[102] See Kurup, A., Maithreyi, R., Kantharaju, B., & Godbole, R. (prepublication). *Trained Scientific Women Power: How Much are We Losing and Why*. Bangalore: Indian Academy of Science; National Academies. (2006). *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, D.C.: National Academics Press. For family-friendly policies, see http://ucfamilyedge.berkeley.edu/initiatives.htm (University of California, Berkeley) and http://www.princeton.edu/dof/policies/family_friendly/ (Princeton University). See also GenSET (2010). Recommendations for Action on the Gender Dimension in Science. Consensus Report. London: Portia http://www.genderinscience.org/downloads/genSET_Consensus_Report_Recommendations_for_Action_on_the_Gender_Dimension_in_Science.pdf; Schiebinger, L., & Gilmartin, S. (2010). Housework is an Academic Issue. *Academe, 96*, 39-44; Schiebinger, L., Henderson, A., & Gilmartin, S. (2008). *Dual-Career Academic Couples: What Universities Need to Know.* Stanford: Clayman Institute for Gender Research.

[103] Stewart, A., LaVaque-Manty, D., & Malley, J. (2004). Recruiting Female Faculty Members in Science and Engineering: Preliminary Evaluation of One Intervention Model. *Journal of Women and Minorities in Science and Engineering, 10*, 361-375.

[104] GenSET (2010). Recommendations for Action on the Gender Dimension in Science. Consensus Report. London: Portia. http://www.genderinscience.org/downloads/genSET_Consensus_Report_Recommendations_for_Action_on_the_Gender_Dimension_in_Science.pdf

knowledge making, human capital, institutional practices and processes, and institutional accountability.

D. MAINSTREAMING SEX AND GENDER ANALYSIS INTO S&T RESEARCH AND DEVELOPMENT

1. Developing methods of gender analysis

Western science—its methods, techniques, and epistemologies—is commonly celebrated for producing objective and universal knowledge, transcending cultural restraints. With respect to gender, ethnicity, and much else, however, science is not value-neutral. Research has documented how gender inequalities, built into society and research institutions, have influenced S&T.[105] Gender bias in research limits S&T's objectivity, development, and potential benefit to society.

Gendered innovations employ gender analysis as a *resource* to stimulate gender-responsible S&T, and by doing so enhance the lives of both men and women around the world.

It is crucially important to identify gender bias and understand how it operates in science and technology. But analysis cannot stop there: focusing on bias is not a productive strategy. Scientists and engineers tend to respond negatively when bias is identified in their work. More importantly, they do not learn how to overcome it. Gender experts in S&T are now shifting emphasis away from critique and toward a positive research programme that employs gender analysis as a *resource* to stimulate gender-responsible S&T.[106] Scientists and engineers respond well when learning how analyzing gender can enhance their research in terms of creativity and social applicability.

Gender mainstreaming—traditionally focused on systems, policies, and institutions—now needs to be extended to research practices. Mainstreaming gender analysis into research leads to gendered innovations. Gendered innovations employ gender analysis as a *resource* to create new knowledge. While many methods of gender analysis exist, there is a need for gender experts, working with scientists and engineers, to develop internationally agreed upon methods of sex and gender analysis that can serve as a baseline for understanding how gender functions in research.

[105] Biology and Gender Study Group. (1989). The Importance of Feminist Critique for Contemporary Cell Biology. In Tuana, N. (Ed.), *Feminism and Science*, pp. 172-187. Bloomington: Indiana University Press; Harding, S. (1991). *Whose Science? Whose Knowledge*. Ithaca: Cornell University Press; Schiebinger, L. (1993). *Nature's Body: Gender in the Making of Modern Science*. Boston: Beacon; Spanier, B. (1995). *Im/partial Science: Gender Ideology in Molecular Biology*. Bloomington: Indiana University Press; L. (1999). *Has Feminism Changed Science?* Cambridge, Mass.: Harvard University Press; Wyer, M. (Ed.) (2001). *Women, Science, and Technology: A Feminist Reader*. New York: Routledge; Wajcman, J. (2007). From Women and Technology to Gendered Technoscience. *Information, Communication & Society, 10 (3)*, 287-298.

[106] Faulkner, W. (2001). The Technology Question in Feminism: A View from Feminist Technology Studies. *Women's Studies International Forum*, *24 (1)*, 79-95; Schiebinger, L. (Ed.), *Gendered Innovations in Science and Engineering*. Stanford: Stanford University Press; Kinge, I. (2008). *GenderBasic: Promoting Integration of the Gender Dimension in Biomedical and Health-Related Research*. Maastricht: Centre for Gender and Diversity, School for Public Health and Primary Care.

It is important to note that the terms 'sex' and 'gender' apply to both men and women. Methods of sex and gender analysis look at both biological sex and gender as a social construct as they relate to science, technology, and innovation.

Methods of sex and gender analysis for S&T are only now being developed.[107] Gender theory has had enormous impact in the humanities and social sciences over the past thirty years and is increasingly being integrated into medicine and the life sciences.[108] What is needed now is to distill and translate these often complex insights into methods readily useful to scientists and engineers. Although projects to develop such methods are currently underway in the United States of America and Europe, there is a need to develop internationally agreed upon methods of sex and gender analysis as recommended in the 2010 GenSET *Consensus Report*.[109] Internationally standardized methods must work across local knowledge systems as well as Western-style sciences and institutions. Emerging methods of sex and gender analysis are shown in the textbox below.

Points to consider:

- Gender mainstreaming needs to be extended to S&T research.
- Gender experts, scientists, and engineers need to work together to develop internationally agreed upon methods of sex and gender analysis that can serve as a baseline for understanding how gender functions in research.
- S&T researchers need to be trained in methods of sex and gender analysis.
- Researchers need to consider all gender methods and think creatively about how these methods can enhance their research.

[107] World Health Organization. (2002). *Gender Analysis in Health: A Review of Selected Tools.* Geneva: WHO; Regitz-Zagrosek, V. (2006). Therapeutic Implications of the Gender-Specific Aspects of Cardiovascular Disease. *Nature Reviews Drug Discovery*, *5*, 1-14; Canadian Institute of Health Research (CHIR). (2010). Gender and Sex-Based Analysis in Health Research: A Guide for CIHR Researchers and Reviewers. http://www.cihr-irsc.gc.ca/e/32019.html; Klinge, I. & Wiesemann, C., (2010). (Eds.) *Sex and Gender in Biomedicine: Theories, Methodologies, Results*. Göttingen: Universitätsverlag; Spitzer, D. (2010); Stanford Gendered Innovations in Science, Medicine, and Engineering Project, 2009-13 in collaboration with the European Union, 2011.

[108] Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspectives. *Feminist Studies*, *14*, 575–599; Harding, S. (1998). *Is Science Multi-Cultural? Postcolonialism, Feminism, and Epistemologies*. Bloomington: Indiana University Press; Oudshoorn, N., Rommes, E., & Stienstra, M. (2004). Configuring the User as Everybody: Gender and Design Cultures in Information and Communication Technologies. *Science, Technology & Values, 29 (1),* 30-63; Wajcman, J. (2007). From Women and Technology to Gendered Technoscience. *Information, Communication & Society, 10 (3)*, 287-298; Schraudner, M. and Lukoschat, H. (Eds.) (2006). *Gender als Innovationspotenzial in Forschung and Entwicklung*. Karlsruhe: Fraunhofer Institut.; Harding, S. (2008). *Sciences from Below: Feminisms, Postcolonialities, and Modernities.* Durham: Duke University Press.

[109] GenSET (2010). Recommendations for Action on the Gender Dimension in Science. London: Portia, 13-15. http://www.genderinscience.org/downloads/genSET_Consensus_Report_Recommendations_for_Action_on_the_Gender_Dimension_in_Science.pdf

Methods of sex and gender analysis*
serve to enhance S&T policy and research. The methods listed here represent a *minimum* set of issues that policy analysts and S&T researchers should consider. As with any set of methods, researchers will fine tune methods to their specific enquiry. The value of these methods depends, as with any endeavor, on the talent and creativity of the research team.

1. **Formulating research questions/Envisioning design**
2. **Analyzing research priorities and social outcomes**
3. **Analyzing sex**
4. **Analyzing gender**
5. **Analyzing covariates (race, ethnicity, age, socioeconomic class, region, etc.)**
6. **Sampling**
7. **Analyzing reference models**
8. **Analyzing knowledge created through social divisions of labour (physical and cognitive)**
9. **Participatory research**
10. **Rethinking language and visual representation**
11. **Rethinking stereotypes**
12. **Analyzing academic disciplines**
13. **Redefining key concepts**
14. **Rethinking theory**

*See appendix

2. Benefits of methods of sex and gender analysis

This section provides several concrete examples of how sex and gender analysis has stimulated the creation of gender-sensitive science and technology. Each example demonstrates a problem, a method of sex or gender analysis important to overcoming the problem, and solutions, or gendered innovations.

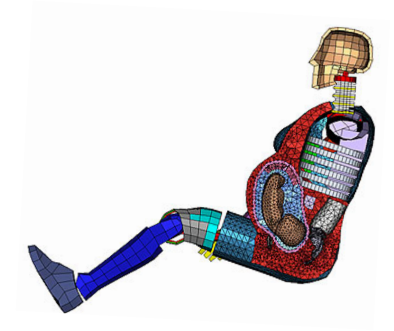
Example 1. Technology design: Pregnant crash test dummies

a. The problem: Conventional seatbelts do not fit pregnant women properly, and in the United States of America , 82 per cent of fetal deaths with known causes result from motor vehicle collisions.[110] Because millions of pregnant women drive every year, the use of seatbelts in pregnancy is a major safety concern.[111] When a lap belt is placed over (rather than under) the pregnant belly, force transmitted through the uterus increases three to four-fold.[112]

Seatbelts were first installed in automobiles in the 1950s, and commonly used since the late 1980s. However, it was not until 1996 that researchers invented pregnant crash test dummies to test crash safety in pregnant women. Even today, many nations do not use pregnant crash test dummies in government-mandated automobile safety testing.

[110] Weiss, H., Songer, T., & Fabio, A. (2001). Fetal Deaths Related to Maternal Injury. *Journal of the American Medical Association, 286 (15)*, 1863-1868.
[111] Ventura, S., Mosher, W., Curtin, S., Abma, J., & Henshaw, S. (2001). Trends in Pregnancy Rates for the United States, 1976-97: An Update. *National Vital Statistics Report, 49 (4)*, 1-9.
[112] Pearlman, M., & Viano, D. (1996). Automobile Crash Simulation with the First Pregnant Crash Test Dummy. *American Journal of Obstetrics & Gynecology, 175*, 977-981.

b. Methods of analysis: It is important to critically question assumptions when 'envisioning design' (method #1). In much engineering design, men are taken as the norm; women are analyzed as an afterthought and often studied from the perspective of how they deviate from the norm. This means that women may be left out of the 'discovery' phase—as a result, many devices are adapted to women retrospectively, if at all. In this case, the three-point seatbelt was designed with no attention to pregnancy. Many years later, a supplementary strap was developed (to hold conventional lap belts in place) in efforts to fix the original design. A better solution might be a completely new basic design, a 4-point seatbelt, perhaps, that works without a lap belt.[113] From the start, devices should be designed for a broad population. This will help ensure safety and a broad user base.



"Linda" by Volvo, the world's first virtual pregnant crash-test dummy.

c. Gendered innovations: Solutions to safety testing are emerging from Sweden. Volvo's 'Linda', designed in 2002 by mechanical engineer Laura Thackray, is the world's first computer simulated pregnant crash-test dummy. 'Linda' generates data modeling the effects of high-speed impact on the woman and fetus. Automobile manufacturers, however, have yet to design an alternative to the 3-point seat belt.

d. Further comments: Using methods of sex and gender analysis from the beginning would have helped engineers avoid leaving out pregnant women. Sampling (method #6) encourages designers to study user populations —and to include both males and females in design development. These males and females should represent people from different regions, social classes, ages, reproductive status, etc. Analyzing sex (method #3) encourages designers to look at sex-specific characteristics of men and women. Pregnancy should not be overlooked.

Example 2. Medical research: Cardiovascular (CVD) disease

a. The problem: CVD is the leading cause of death for women in the United States of America, Europe, and in many developed countries.[114] Despite this, CVD has long been defined as a male disease, and clinical standards and treatments have been developed for men.

b. Methods of analysis: Researchers must analyze disease reference models (method #7). In the case of CVD, myocardial infarction (MI) or 'heart attack' symptoms were modeled on men and the results generalized to the entire population. Symptoms, however, are very different for men and for women. Men typically experience pain in the chest and left arm. Women more often experience nausea and vomiting, pain in the right arm and back, fatigue, cold sweat, and

[113] Duma, S., Moorcroft, D., Gabler, H., Manoogian, S., Stitzel, J., & Duma, G. (2006). Analysis of Pregnant Occupant Crash Exposure and the Potential Effectiveness of Four-Point Seatbelts in Far Side Crashes. *Virginia Tech—Wake Forest Center for Injury Biomechanics Accident Reconstruction Newsletter*, March 7.

[114] American Heart Association (AHA). (2010). Women and Cardiovascular Disease Fact Sheet. *http://www.americanheart.org/downloadable/heart/1267456190628TD%20edited%20FINAL%20women%20and%20CVD%2002.15.10.pdf*

dizziness. Because women's symptoms do not match the 'accepted' (male) symptoms, women are often misdiagnosed and improperly treated.[115]

c. Gendered innovations: Including women as research subjects (analyzing sex method #3) has lead to the discovery of important sex differences in MI symptoms, diagnostic testing, and preventative therapies. Further, analyzing covariates (method # 5) has led to the discovery that risk differs significantly by ethnicity and socioeconomic class. In the United States of America , African American women have 28 per cent higher CVD mortality compared to the overall female population.[116]

d. Further comments: Analyzing *gender* (method #4) can also enhance women's health care. In the United States of America , women are 52 per cent more likely than men to experience delays in hospital transport after calling for emergency medical assistance.[117] The reasons are not fully understood, but a 2009 review suggests that delays result from emergency teams considering women's 'modesty' when placing chest leads during on-site EKGs or from patient choice in hospital destination.[118] Understanding this phenomenon can help medical teams overcome it.

Example 3. Osteoporosis: Sex and gender analysis also benefits men

a. The problem It is important to understand that 'gender' relates to men as well as women. Osteoporosis is a disease traditionally seen as affecting post-menopausal women, and men have historically been excluded from osteoporosis research in much the same way as women have been excluded from CVD research. Current diagnostic criteria for osteoporosis are based on the relationship between bone mineral density (BMD) and fracture risk in postmenopausal white women, resulting in underdiagnosis of osteoporosis in men.[119] Yet men suffer from a third of all osteoporotic-hip fractures, and have higher average mortality than women with similar injuries.[120]

b. Methods of analysis: Examining sex in diagnostic reference models (method #7) in osteoporosis research has broken the gender paradigm and turned attention to understanding the disease in men.

c. Gendered innovations: As a result, diagnostic criteria are beginning to include men.[121]

d. Further comments: Gender experts generally have not studied how science and technology fail men. Baby strollers and shopping carts are two artefacts that have been designed for women rather than men. In these cases, gender relations (the fact that women tend to care for young children and do household shopping in developed countries) have been designed into everyday

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[115] Mosca, L., Manson, J., Sutherland, S., Langer, R., Manolio, T., & Barrett-Connor, E. (1997). Cardiovascular Disease in Women: A Statement for Healthcare Professionals from the American Heart Association. *Circulation, 96,* 2468-482.

[116] American Heart Association. (2009). Women and Cardiovascular Disease Fact Sheet.

[117] Concannon, T., Griffith, J., Kent, D., Normand, S., Newhouse, J., Atkins, J., Beshansky, J., & Selker, H. (2009). Elapsed Time in Emergency Medical Services for Patients With Cardiac Complaints: Are Some Patients at Greater Risk for Delay? *Circulation, 2 (1),* 9-15.

[118] Ornato, J. (2009). Gender Delay in Emergency Medical Services: Does it Really Exist? *Circulation, 2 (1),* 4-5.

[119] Faulkner, K. & Orwoll, E. (2002). Implications in the Use of T-Scores for the Diagnosis of Osteoporosis in Men. *Journal of Clinical Densitometry, 1 (5),* 87-93.

[120] Sweet, M., Sweet, J., Jeremiah, M., & Galazka, S. (2009). Diagnosis and Treatment of Osteoporosis. *American Family Physician, 3 (79),* 193-200.

[121] Cummings, S., Cawthon, P., Ensrud, K., Cauley, J., Fink, H., & Orwoll, E. (2006). BMD and Risk of Hip and Nonvertebral Fractures in Older Men: A Prospective Study and Comparison with Older Women. *Journal of Bone and Mineral Research, 10 (21),* 1550-1556.

objects. These objects tend to reinforce inequalities in gender relations in that men, attempting to push a baby carriage, may experience discomfort or injury.

Example 4. Conservation of biodiversity among the Subanen in the Philippines

a. The problem: The Subanen peoples living in the Philippines are, like many marginalized rural groups, afflicted by material poverty and often depend on natural resources for foods and medicines. However, deforestation and climate change are threatening plant biodiversity, and increased migration of young people to cities is undermining ethnobotanical knowledge.[122]

b. Methods of analysis: Local knowledges play an important role in discussions of gender and S&T. Local knowledges develop over generations and are passed down, often orally, from generation to generation—often from woman to girl. Analyzing knowledge created through social divisions of labour (method #8) helps researchers understand that women may be the keepers of specific knowledges. Women are 60-90 per cent of agricultural workers in the developing world, and they are also often the first providers of family health care. As such, they have developed unique ethnobotanical knowledge about medicinal uses and processing of plants.[123] If local women are not part of the STI development process, knowledge and skills crucial to the success of a particular project may be overlooked or even destroyed.

STI policies often see women, especially women in developing countries, as 'receivers' of knowledge and technologies. Participatory research (method #9) recognizes women and men as holders of local knowledges and makes them active participants in solving local problems. Participants with local knowledges are viewed as innovators with intellectual resources to contribute to finding solutions.

c. Gendered innovations: Between 2003 and 2004, the International Research Centre for Agroforestry (IRCA) worked with the Subanen community in the Philippines to help them document their ethnobotanical knowledge, much of which is held by women. The participatory research team engaged interdisciplinary experts—8 men and 5 women—from both the IRCA and the Subanen community. The project allowed the community to secure food supplies and medicines for local households in several ways. First, local women identified and documented the hundred-plus cultivars of rice they manage in order to preserve threatened strains. Second, the project recorded 200 wild forest plant species (used for sustenance when crops fail) in efforts to better preserve them. Third, the project documented medicinal plants traditionally collected in the forest so that local women can cultivate them in backyard or communal gardens.

d. Further comments: Securing intellectual property rights to local knowledge—including women's knowledge—is important. A memorandum of understanding based on specific requests and stipulations of the communities was signed by all project partners.

Example 5. Civil engineering to secure water supplies

a. The problem: Millions of people worldwide lack reliable, efficient access to water.

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[122] Suminguit, V. (2005). Indigenous Knowledge Systems and Intellectual Property Rights; An Enabling Tool for Development with Identity. Paper prepared for the Workshop on Traditional Knowledge, the United Nations and Indigenous Peoples, Panama City.

[123] Huyer, S. (2004). Gender and Science and Technology from an International Perspective. Position paper prepared for the Gender Advisory Board - United Nations Commission on Science and Technology for Development. Washington D.C.; Juma, C. and Yee-Cheong, L. (2005). *Innovation: Applying Knowledge in Development.* London: United Nations Development Programme, 91.

b. Methods of analysis: Analyzing social divisions of labour (method # 8) helps researchers understand who in a community holds the knowledge required for a particular project. Women, as traditional water fetchers, often have specialized knowledge concerning water sources. Participatory research (method # 9) calls for women with specialized knowledge to be engaged in development projects from the start.
c. Gendered innovations: Social divisions of labour in the United Republic of Tanzania's Kilombero district make water procurement women's work. Consequently, women have detailed knowledge of soils and their water yield. Civil engineering teams deciding on well placement found that tapping into women's knowledge provides the best water yields. After conducting an evaluation of 122 water projects, the World Bank determined that projects involving women were on average six to seven times more effective than projects excluding women.[124]

3. Mainstreaming the use of methods of sex and gender analysis

Mainstreaming sex and gender analysis into basic and applied research requires that researchers and S&T policy makers are trained in specific methods, so that they can address gender issues where appropriate. It is also important to note that increasing the number of women in science does not, in and of itself, lead to gender-responsive science. Women may harbour unconscious gender biases as much as men. Similarly, an interest in 'women's issues' does not automatically translate into expertise in gender analysis. Expertise in gender analysis requires systematic training as in any other field of intellectual endeavour.

Gender analysis should be taught throughout the curriculum, including basic science, medicine, and engineering curricula, at the primary, secondary, and tertiary levels. It is important that research institutions support Gender Studies programmes where experts develop new knowledge on gender, science, and technology. At the same time, gender analysis must be taught to future S&T researchers. By mainstreaming gender analysis throughout the curriculum, the boundary between 'gender studies' and 'science' disappears; gender issues are fully integrated into S&T studies. In this way, students in technical fields learn methods of sex and gender analysis continuously throughout their studies.

Integrating sex and gender into the basic curriculum has been most successful in medicine. In the Netherlands, Radboud University's Nijmegen Medical Center has ongoing projects to do this.[125] In Canada, between 2002 and 2006, six medical schools produced the 'Gendered Lens', a web-based resource that introduces gender issues in four areas, including cardiovascular disease and lung cancer.[126] In 2006, the United States National Institutes of Health Office for Research on Women's Health launched a six-lesson course on the 'Science of Sex and Gender in Human Health'.[127] While excellent, each of these latter-two resources focus

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[124] Fisher, J. (2006). *For Her it's the Big Issue: Putting Women at the Centre of Water Supply, Sanitation and Hygiene*. Geneva: Water Supply and Sanitation Collaborative Council

[125] Verdonk, P., Benschop, Y., deHaes, H., & Lagro-Janssen, T. (2009). From Gender Bias to Gender Awareness in Medical Education. *Advances in Health Science Education, 14,* 135-152; Agogino, A., Newman, C., Bauer, M., & Mankoff, J. (2004). Perceptions of the Design Process: An Examination of the Gendered Aspects of New Product Development. *International Journal of Engineering Education, 20 (3),* 452-460.

[126] The 'Gendered Lens' is part of Canada's Gender and Health Collaborative Curriculum Project. http://genderandhealth.ca/

[127] NIH Office of Research on Women's Health (NIH), and the Food and Drug Administration Office of Women's Health. The Science of Sex and Gender in Human Health. http://sexandgendercourse.od.nih.gov/index.aspx

on women’s health as a separate subject and leave it to the educator to mainstream relevant information into the basic medical curriculum.

The Gendered Innovations Project at Stanford University recently collected information about basic science and engineering courses that mainstream sex and gender.[128] Such courses are rare. More common are specialized courses on sex or gender, some of which directly relate to S&T. These courses, however, tend to be given in humanities or social science departments and not as part of basic S&T education. There is a need to collect model courses that integrate sex and gender methods into basic science education. Where these do not exist, there is a need to support interdisciplinary teams to create such courses.

In addition, there are several practical ways to encourage researchers to develop expertise in sex and gender analysis:

a. Granting agencies can require that all applicants include gender methodology in research design. The European Union has such policies (see above pp. 8-9).
b. Hiring and promotion committees can evaluate researchers and educators on their success in implementing gender analysis. Knowledge and use of methods of sex and gender analysis can be one factor taken into consideration by institutions in hiring and promotion decisions.
c. Editors of peer-reviewed journals can require sophisticated use of sex and gender methodology when selecting papers for publication. A number of journals do this: the *Journal of the American College of Cardiology*, and *Circulation*, the American Heart Association journals. *Nature* is considering adopting this policy.[129]

E. CONCLUSION

Governments, the private sector and other stakeholders recognize that support for S&T is an essential investment for economic development. Innovations—new sciences and technologies, and their applications—can create economic returns as well as improve the well-being of citizens in terms of employment opportunities and standards of living. However, national science, technology, and innovation (STI) policies too rarely adequately address the full range of gender issues that are connected with S&T. While STI policies tend to support women’s participation in S&T, they rarely consider the need for institutional transformation or the gender dimensions of research and development.

This shortcoming is also apparent at the international level. For example, the United Nations Millennium Project's Science, Technology, and Innovation Taskforce[130] stated that “women are central to economic and social development,” and recognized that “reducing gender inequality is essential for reducing hunger, containing HIV/AIDS, promoting environmental

[128] Stanford Gendered Innovations in Science, Medicine, and Engineering Project, 2009-13. Draft of the project can be viewed at: http://genderedinnovations.stanford.edu/ User id: gender; password: analysis. See ‘Educators’.
[129] JACC Instructions for authors: http://content.onlinejacc.org/misc/ifora.dtl; *Circulation:* Instructions to Authors state: “Please provide sex-specific and/or racial/ethnic-specific data, when appropriate, in describing outcomes of epidemiologic analyses or clinical trials; or specifically state that no sex-based or racial/ethnic-based differences were present”. http://circ.ahajournals.org/misc/ifora.shtml; *Nature* http://www.nature.com/nature/journal/v465/n7299/full/465665a.html
[130] The United Nations Millennium Project is an independent advisory body commissioned by the UN Secretary-General to propose the best strategies for meeting the Millennium Development Goals (MDGs).

sustainability" and achieving development goals generally.[131] This taskforce, however, did little to analyze how women and gender issues figure in the three platform technologies – information and communication technology, biotechnology, and nanotechnology – identified as critical for developing countries in the next decade. Several suggestions were made concerning how these technologies might be used by women, but the basic technology platforms are being developed without attention to gender.

STI plays an important role in development that will only increase in the coming years. It is crucial that gender analysis be mainstreamed into all aspects of this work, including policies, programmes, and funding arrangements. It is also important that women's organizations routinely address science and technology in their work.[132] For both STI policy makers and women's organizations, the issue may be one of lack of awareness and of training, as relatively few of them have expertise in both S&T and gender issues.

APPENDIX: METHODS OF SEX AND GENDER ANALYSIS (short descriptions only)

1. Formulating research questions/Envisioning design:

Researchers should critically analyze the assumptions about sex and gender that shape their research. What does the research community assume—what are the shared preconceptions and practices? What are the researcher's own assumptions about sex and gender? Uncovering these 'blind-spots', or unexamined assumptions, may open new areas of research and ensure that research benefits both men and women.

2. Analyzing research priorities and social outcomes:

Researchers should consider how research priorities are set and examine social outcomes. Ethics should be part of the basic research design and not applied separately or after the fact. Key questions include: who benefits, and who does not, from a particular research project?

3. Analyzing sex:

Researchers should include both male and female subjects in studies, and disaggregate data by sex—whether test subjects are humans, animals, single cells, or biological products of such. Results should report: sex differences found or null finding. Research should also examine gender and other confounders (ethnicity, socioeconomic class, age, geographic region, etc.) before attributing differences between males and females to biological sex.

4. Analyzing gender:

Gender refers to the social attributes and opportunities associated with being male and female. These attributes, opportunities and relationships are socially constructed and are learned through socialization processes. They are context/time-specific and changeable. Any observed sex differences may in fact be caused by gendered variables, such as social divisions of labour or life styles. Researchers should analyze cultural factors related to gender when sex differences are observed.

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[131] Millennium Project. (2005). *Investing in Development: A Practical Plan to Achieve the Millennium Development Goals*. London: Earthscan Publishing; Organization for Economic Cooperation and Development (OECD). (2008). *Science, Technology, and Industry Outlook*. Paris: OECD Publications.

[132] Samson, A. (April 2006). Gender and Science, Technology, and Innovation. Prepared for International Development Research Centre of Canada, Innovation, Policy, and Science Programme Area.

5. Analyzing covariates:

Men as well as women differ by factors such as race and ethnicity, age, socioeconomic status, geographical location, type of employment, educational background, sexual orientation, religion, and other significant aspects. Without covariate analysis, it is difficult to assign differences between groups to sex, gender, or any other specific causal factor. Understanding how these factors interact many also help to explain the effects of sex and gender.

6. Sampling:

Populations studied must be representative with respect to sex, gender, race, ethnicity, age, socioeconomic class, genotype, or other relevant characteristics.

7. Analyzing reference models:

Reference models are created as heuristic devices used to better understand physical and cultural phenomena. These models can bias research in specific ways. In much medical research, for example, males have been taken as the standard model; females are studied as deviations from that model. Reference models should be analyzed for how inclusion and exclusion bias results.

8. Analyzing knowledge created through social divisions of labour:

Social divisions of labour can create unique knowledges. Researchers need to recognize that men and women often have different social, cultural, physical, and cognitive experiences related to sexual divisions of labour. These experiences stem from sex differences (for example, females become pregnant and males do not) as well as gender differences (for example, men and women often have different roles in the workforce).

9. Participatory research:

STI policies often see women, especially women in developing countries, as 'receivers' of knowledge and technologies. Participatory research recognizes holders of local knowledges as active participants in solving local and global problems.

10. Rethinking language and visual representation:

In addition to mathematics, language is a prime glue of scientific culture, and much gender analysis has focused on the rhetoric of scientific texts and images. Analogies and metaphors construct as well as describe—they have both a hypothesis-creating and proof-making function in science. Language and images should be analyzed for unintended gendered messages.

11. Rethinking stereotypes:

A stereotype is a widely held, usually fixed, and often oversimplified belief. Stereotypes can apply to social groups, scientific disciplines, and fields of employment. Researchers' beliefs and stereotypes about sex and gender can influence the kinds of questions they ask. Researchers should examine core assumptions to avoid harmful stereotypes.

12. Analyze academic disciplines:

Academic fields of study, or disciplines, are the basic units organizing universities and research institutions. Disciplines produce their own economies of value, mediate employment in S&T, regulate funding from universities and governments, and confer and guard prestige. The current movement towards interdisciplinarity indicates that traditional disciplines may not divide knowledge in the most productive way for global S&T. Researchers should analyze how disciplinary boundaries may limit the types of questions they examine.

13. Redefining key concepts:

Like language, key concepts can both describe and construct phenomena. Researchers should scrutinize assumptions related to sex and gender in their key concepts. ‘Out-of-position’ drivers (p. 3 above) is an example of a key concept that normalizes people excluded from the standard design by conceptualizing them as ‘out-of-position’. This suggests that something is wrong with the drivers who do not ‘fit’ the design rather than something wrong with the design itself.

14. Rethinking theory:

Theory, in a particular field, determines what constitutes significant research, what needs explanation, and what counts as evidence. Considering gender issues may require reformulating basic theories that govern research. In evolutionary theory, for example, designating only certain stone objects, such as arrowheads and hand axes, as ‘tools’ has led theorists to see early human society as dominated by men. Shifting definitions of tools to include artefacts used for nutting, leatherworking, and grain harvesting has allowed theorists to better understand women’s role in early human societies.