UN Women

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Priority Theme: Innovation and Technological Change, and Education in the Digital Age for Achieving Gender Equality and The Empowerment of all Women and Girls

This Report: Harnessing Technology and Innovation to Achieve Gender Equity and Empower all Women and Girls

Londa Schiebinger, John L. Hinds Professor of History of Science, Founding Director, Gendered Innovations in Science, Health & Medicine, Engineering, and Environment, Stanford University, Stanford, California, United States of America with the assistance of Julia Fine, PhD Candidate, Department of History, Stanford University, and Chandra Vadhana Radhakrishnan, Gendered Innovations Lab, Stanford University.

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Part 1. Introduction

Much has been written on gender in technology, including my United Nations (UN) Division for the Advancement of Women (now incorporated into UN Women) background paper, "Gender, science and technology" (2010), Prof. Judy Wajcman's background paper, "The digital revolution: Implications for gender equality and women's rights 25 years after Beijing" (2019), and the Organisation for Economic Co-operation and Development (OECD)'s "Bridging the digital gender divide: Include, upskill, innovate" (2018).

Governments, non-governmental organizations (NGOs), governmental agencies, public and private funding agencies, educational institutions, and private industry have taken three strategic approaches to gender equality over the past several decades:

1. "Fix the Numbers" focuses on increasing the numbers of women and underrepresented groups in science and technology (S&T). All three reports mentioned above discuss and offer recommendations on this subject. As summarized by the OECD, "Women are under-represented in information and communication technologies (ICT) jobs, top management and academic careers, and men are four times more likely than women to be ICT specialists. At 15 years of age, on average, only 0.5% of girls wish to become ICT professionals, compared to 5% of boys. Women-owned start-ups receive 23% less funding and are 30% less likely to have a positive exit compared to male-owned businesses."[1]

2. "Fix the Institutions" promotes gender equality in societies and careers through structural change. Again, the three reports above treat these topics. As summarized by the OECD: "…hurdles to access, affordability, lack of education as well as inherent biases and socio-cultural norms curtail women and girls' ability to benefit from the opportunities offered by the digital transformation. … If one adds to this the fact that women receive comparatively less financing for their innovative endeavours and are often confronted with "glass ceilings" curbing their professional ambitions (especially so in tech industries), the picture that emerges is far from positive and points to a vicious circle that could lead to a widening of digital gender divides."[2]

3. "Fix the Knowledge" or "gendered innovations" stimulates excellence in science and technology by integrating sex, gender, and intersectional analysis into research.[3,4] This report focuses on gender dynamics in knowledge production. It is important to recognize that gender norms shape technologies, and that technologies, in turn, shape gender and other social norms. S&T often reinforce *vicious* cycles where past inequalities are amplified and perpetuated into the future. These cycles of inequalities can be broken by integrating sex, gender, and intersectional analysis into research design. The goal is to create S&T that are designed—from the very beginning—with gender and other social factors top of mind. Innovations in technologies can lead to *virtuous* cycles that restructure sociocultural gender norms and ultimately contribute to achieving the UN Sustainable Development Goals (SDGs). The goal

[1] Organisation for Economic Co-operation and Development (OECD). (2018). Bridging the digital gender divide: include, upskill, innovate. *OECD*.
[2] OECD. (2018). Bridging the digital gender divide: include, upskill, innovate.
[3] Tannenbaum, C., Ellis, R. P., Eyssel, F., Zou, J., & Schiebinger, L. (2019). Sex and gender analysis improves science and engineering. *Nature*, *575*(7783), 137–147. https://doi.org/10.1038/s41586-019-1657-6
[4] Gendered Innovations, http://genderedinnovations.stanford.edu/

of gendered innovations is to promote scientific excellence, social equity, and environmental sustainability.

This report focuses on gender in technology but takes an expansive view to suggest where intersectional approaches that include race and ethnicity, geographic location, and educational background may be relevant. The paper also summarizes where gender and intersectional analysis have led to innovations that empower girls and women while simultaneously promoting environmental sustainability. We recommend structural solutions to long-standing problems. Only by understanding the role knowledge production plays can we solve the problem of equitable participation in S&T.

Part 2. Challenges and opportunities of using technology to accelerate progress for gender equity and bring systemic change in various economic and social sectors

Artificial intelligence (AI)/Machine learning (ML)/Social assistive robots

AI, ML, and robotics are powerful digital tools increasingly used in healthcare, education, transportation, and e-commerce. Yet, historic and real-time bias built into these technologies can augment cycles of discrimination. Technologies often reinforce vicious cycles where past inequalities are amplified into the future. The examples here are numerous and exist across a number of technological sectors.

In *Google Search*, men are five times more likely than women to be offered ads for high-paying executive jobs.[5] The problem here is with the data. Google indexes the internet broadly, meaning that the dataset for such searches include historic earnings for men and women, and embed the historic pay gap data showing that women overall earn less than men overall. Women worldwide only make 77 cents for every dollar earned by men.[6] The Google search algorithm returns ads for current jobs based on this historical data, meaning that the technology perpetuates and augments a cycle of discrimination.

For similar reasons, *Google Translate* defaults to the masculine pronoun in English, amplifying historic bias. Google Translate defaults to the masculine pronoun because “he said” is more commonly found on the world-wide web of the English language than “she said.” We know from Google Ngram Viewer that the ratio of “he said” to “she said” has fallen dramatically from a peak of 4:1 in the 1960s to 2:1 since 2000. This parallels movements, including the international women’s movements of the 1960s and governmental programs beginning especially in the 1980s, to increase the numbers of women in science and technology. With one algorithm, Google unintentionally wiped out 40 years of revolution in language. This is unconscious gender bias at play.

This unconscious gender bias from the past amplifies gender inequality into the future. When a translation program defaults to "he said," it reinforces the stereotype that men are active intellectuals by underrepresenting women in this role. This increases the relative frequency of the masculine pronoun on the web that may reverse hard-won advances toward gender equality.

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[5] Datta, A., Tschantz, M. C., & Datta, A. (2015). Automated experiments on ad privacy settings. *Proceedings on Privacy Enhancing Technologies, 2015* (1), 92-112.

[6] UN Women, Equal pay for work of equal value, https://www.unwomen.org/en/news/in-focus/csw61/equal-pay

Google has implemented modest fixes over the past decade, but the basic problem persists. It's often harder to fix a technology once the basic platform is set. Importantly, Google translate is creating the future: our devices, programs, and processes shape human attitudes, behaviors, and culture. In other words, past bias is perpetuated into the future, even when governments, universities, and companies themselves have implemented policies to foster equality.[7]

Similar problems of historically biased or unrepresentative data create bias in *computer vision*. The demand for ever larger training data often produces datasets that overrepresent dominant groups and underrepresent others. For example, over 45 percent of ImageNet data, which fuels research in computer vision, comes from the U.S., a country that represents only 4 percent of the world's population. By contrast, China and India together make up only 3 percent of ImageNet even though they represent 36 percent of the world's population. This lack of geodiversity in open datasets has led to the "bride" problem, where algorithms label a photo of a traditional U.S. bride dressed in white as "bride," "dress," "woman," "wedding," but mislabel a photo of a North Indian bride, for instance, as "costume" and "performance art."[8]

Other examples of such historically biased data are plentiful. In *natural language processing* (NLP), word embeddings perpetuate historical patterns of discrimination. Word embedding maps each English word (in this case the corpus is the English language on the World Wide Web) to a point in space (a geometric vector) such that the distance between vectors captures semantic similarities between words. Thus, word embedding capture analogies such as "man" is to "king" as "woman" is to "queen." It also returns historical patterns of social patterns that we today see as stereotypes undergirding inequalities. In relation to gender, word embeddings returned, for example, that "man" is to "computer programmer" as "woman" is to "homemaker."[9] In relation to ethnicity, word embeddings returned the stereotypes that Asians are "inhibited," "passive" and "sensitive".[10]

Technologists are increasingly designing *social assistive robots* to interact with humans in hospitals, elder care facilities, classrooms, homes, airports, and hotels. Individuals of different gender identities may have different needs and social preferences, and designers should aim for gender-inclusive design.[11] Gender-inclusive design is not "gender-blind" or "gender-stereotypical," but design that considers the unique needs of distinct social groups.

The challenge for roboticists is: 1) to understand how gender becomes embodied in robot; 2) to design robots that promote social equality by challenging current stereotypes.[12]

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[7] Gendered Innovations, Machine Translation, http://genderedinnovations.stanford.edu/case-studies/nlp.html#tabs-2

[8] Shankar, S., Halpern, Y., Breck, E., Atwood, J., Wilson, J., & Sculley, D. (2017). No classification without representation: Assessing geodiversity issues in open data sets for the developing world (arXiv:1711.08536). arXiv. https://doi.org/10.48550/arXiv.1711.08536

[9] Bolukbasi, T., Chang, K.-W., Zou, J., Saligrama, V., & Kalai, A. (2016). Quantifying and reducing stereotypes in word embeddings (arXiv:1606.06121). arXiv. https://doi.org/10.48550/arXiv.1606.06121

[10] Garg, N., Schiebinger, L., Jurafsky, D., & Zou, J. (2018). Word embeddings quantify 100 years of gender and ethnic stereotypes. *Proceedings of the National Academy of Sciences*, *115*(16), E3635–E3644. https://doi.org/10.1073/pnas.1720347115

[11] Wang, Y., & Young, J. E. (2014). Beyond "pink" and "blue": Gendered attitudes towards robots in society. *Proceedings of Gender and IT Appropriation. Science and Practice on Dialogue - Forum for Interdisciplinary Exchange*, 49–59.

[12] Gendered Innovations, Gendering Social Robots, http://genderedinnovations.stanford.edu/case-studies/genderingsocialrobots.html#tabs-2

Again, it is important to recognize that social norms shape technologies and that technologies, in turn, shape social norms. Designers have the opportunity to turn vicious cycles into virtuous cycles of cultural change. As the image (right) shows, technologies are designed into cultures alive with social norms. Technologists have the opportunity to challenge gender norms with their designs. Technologies can then embody social norms that promote equality by challenging and reformulating user expectation. This, in turn, prompts users to rethink social norms. These novel designs ultimately influence culture and help develop new more equitable societies.

Recommendations: Rebuilding technology infrastructure to promote human-rights based research

Policy is one driver of technology that can catalyze structural solutions that foster social equity and environmental sustainability. These recommendations require the pillars of technology infrastructure—funding agencies, peer-reviewed journals and conferences, institutions of higher education, and industry to coordinate policies[13]:

These recommendations are based upon several different approaches:

1. **United Nations Human-Rights Based Technology**: Human rights are "rights that are inherent to all human beings, regardless of race, sex, nationality, ethnicity, language, religion, or any other status. Human rights include the right to life and liberty, freedom from slavery and torture, freedom of opinion and expression, the right to work and education, and many more."[14]

2. **AI Principles** (e.g., as articulated at the Asilomar Conference, 2017, and endorsed by 5720 signatories): safety, responsibility, human values, rights, dignity, and freedoms.[15] None of these principles, however, explicitly treat gender, race, or intersectional analysis.

2. **Responsible Computing Research**. The U.S. National Academies committee, chaired by Barbara J. Grosz, released a comprehensive report on Responsible Computing released in 2022. Responsible computing" refers to both intrinsic ethics, including autonomy and freedom, well-being, relational and material equality, justice and legitimate power, collective self-determinism, and thriving natural environment; and instrumental ethics, including fairness, trust, verifiability, safety, security, transparency, inclusiveness and diversity, etc. Responsible computing research is carried out using humanistic, social and behavioral science analysis to understand how computing research not only shapes, but also is shaped by a range of values, priorities, influences, and effects. Their key recommendation gets to the heart of the matter: "the computing research community should reshape

[13] Tannenbaum, C., Ellis, R. P., Eyssel, F., Zou, J., & Schiebinger, L. (2019). Sex and gender analysis improves science and engineering. *Nature*, *575*(7783), 137–147. https://doi.org/10.1038/s41586-019-1657-6
[14] https://www.un.org/en/global-issues/human-rights
[15] Future of Life Institute, Asilomar AI principles, https://futureoflife.org/2017/08/11/ai-principles/

the ways computing research is formulated and undertaken to ensure that ethical and societal consequences are considered and addressed appropriately from the start" (p. 75).[16]

Research funders need to reconfigure granting processes to support interdisciplinary work between technologists, on the one hand, and humanists and social and behavioral scientists, on the other—these disciplines are often siloed in different branches of funding agencies. Funding can incentivize new research partnerships. Proposal evaluation needs to consider both the technical excellence and the social benefits of a proposal, with special attention to gender, race, and intersectional social analysis. For example, Human-Centered AI Institute at Stanford University funding requires review of projects by a panel of technologists and a panel of humanists and social scientists. By putting these policies into place, research agencies ensure that research is done right from the very beginning.

Proposal evaluators—both technologists and social scientists—need to be trained in these approaches.

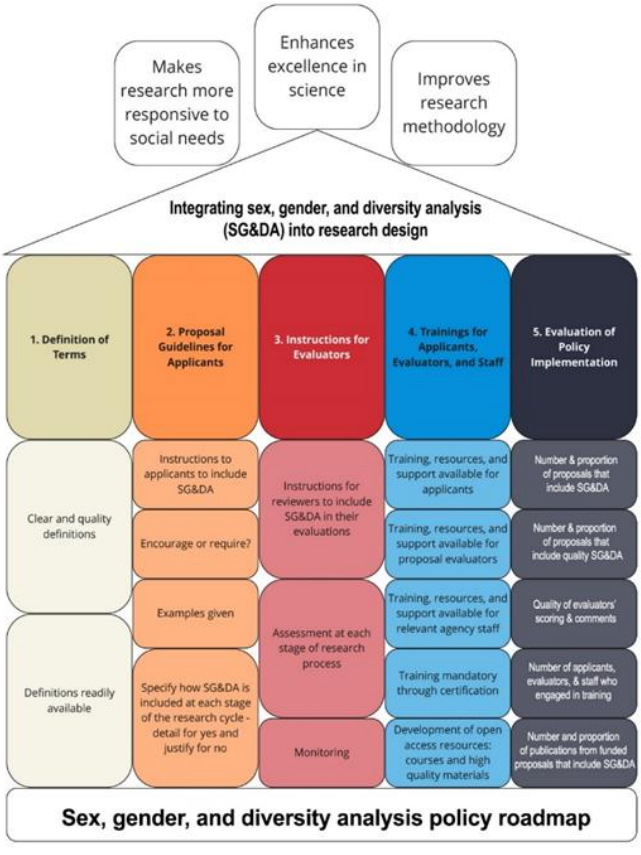
This pillar includes both publicly funded granting agencies, such as the European Commission, the National Research Foundation of Korea, or the National Research Foundation of South Africa, as well as private foundations, such as the Gates Foundation, Wellcome Trust, or Oswaldo Cruz Foundation, and NGOs. The important point is that funders should support research that benefits everyone across the whole of society.

Globally, the European Commission is a leader in this area and has had policies for integrating sex and gender into research content since 2003. Their new funding framework launched in 2020, Horizon Europe, strengthened this requirement. Applicants are now *required* to integrate sex, gender, and intersectional analysis into the design of research—or to justify that it is not relevant to the work.[17]

[16] National Academies of Sciences, Engineering, and Medicine. (2022). *Fostering responsible computing research: Foundations and practices.* Washington, DC: The National Academies Press. https://doi.org/10.17226/26507

[17] Schiebinger, L. & Klinge, I. (2020). Gendered Innovations 2: How Inclusive Analysis Contributes to Research and Innovation. Luxembourg: Publications Office of the European Union.

A recent study analyzed sex, gender, and diversity analysis (SG&DA) policy at 22 publicly funded agencies across six continents.[18] A policy roadmap for effective integration of SG&DA into research was developed as part of this study. In the electronic version on the Gendered Innovations website (see image), policy makers can click on each of the five sections to see emerging global policies.[19] While agencies can share policies and practices to enhance research collaboration across global regions, each agency will develop country-specific policies that accommodate their specific cultural practices and regulatory landscapes. To my knowledge, there is no study of private foundation or NGOs policies for encouraging SG&DA in funded research. This will be an important next step.



Editorial boards of peer-reviewed journals and conferences can support these efforts by requiring sophisticated sex, gender, race, intersectional, and broader social analysis when selecting papers for publication. The NeurIPS (Neural Information Processing Systems) conference, for example, conducts ethical reviews before accepting papers.[20] Journals, such as *Nature* and *The Lancet*, require sex and gender analysis, where relevant.[21]

Institutions of primary, secondary, and higher education, colleges and universities, and research institutions can integrate knowledge of sex, gender, race, intersectional, and broader social analysis into core engineering, design, and computer science curricula. Many universities host stand-alone courses on these topics in the humanities and social sciences. These are very important. But it is also imperative that *critical intersectional sociocultural analysis* be embedded in core courses across the natural sciences, medicine, and engineering curricula. These courses should be required in the major. At the same time, humanists and social scientists need to prepare their students for these types of collaboration.

Universities train the workforce for the future. Universities that prepare student to understand the cultural impacts of their research can influence industry by preparing their technologists to consider social benefits and harms as they design products, services, and infrastructures.

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[18] Hunt, L., Nielsen, M.W., Schiebinger, L. (2022). A framework for sex, gender, and diversity analysis in research: Funding agencies have ample room to improve their policies. *Science*, 377 (6614) (2022), 1492-1495.
[19] Gendered Innovations, Mapping Emerging Practices for Public Granting Agencies, http://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-major-granting-agencies.html
[20] https://blog.neurips.cc/2021/08/23/neurips-2021-ethics-guidelines/
[21] Gendered Innovations, Sex and Gender Analysis Policies of Peer-Reviewed Journals, http://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-peer-reviewed-journals.html

Emerging courses:

- Since 2017, universities have been developing what was first called at Harvard "Embedded EthiCS," courses that embed ethical reasoning in core CS courses.[22] We recommend embedding critical intersectional sociocultural analysis that draws skills broadly from the humanities and social sciences.
- The Mozilla Teaching Responsible Computing Playbook outlines specific ways to educate students in critical thinking. This is done largely by interdisciplinary collaborations of computer scientists and humanists.[23]
- Teaching Responsible Computing (University of Buffalo) redesigned a first-year seminar to include coursework (lecture slides, assignments, recitation activities) specifically on critical approaches to computing. The course culminates in a competition where students pitch solutions to social problems (e.g., antiracist computing).[24]

Industry. Numerous companies have promoted AI Principles similar to those articulated at the Asilomar Conference in 2017.[25] It will be important to survey and audit company principles for inclusion of gender, race, and intersectional analysis. Industry can facilitate achieving their AI Principles by hiring employees trained to work in interdisciplinary teams that include technologists, humanists, and social scientists, and who have cultivated skills to evaluate the potential social benefits and potential social harms of their products, services, and infrastructures.

Additional recommendations in this area:

Industry and academic researchers tend to design to international and national laws and regulations. These are in the process of being implemented.

1. Global initiatives that work to promote responsible computing should be audited to ensure they incorporate gender issues and include gender experts. Modeled loosely on the International Panel on Climate Change, the Global Partnership on Artificial Intelligence (GPAI) was launched in 2020. The partnership guides the responsible development, use, and adoption of AI that is human-centric and grounded in human rights, inclusion, diversity, and innovation, while encouraging sustainable economic growth.[26] The founding members are Australia, Canada, the European Union, France, Germany, India, Italy, Japan, Rep. Korea, Mexico, New Zealand, Singapore, Slovenia, the U.S., and the U.K. The report does not explicitly mention gender.

A model global initiative is United Nations Educational, Scientific and Cultural Organization (UNESCO)'s *Recommendations on the Ethics of Artificial Intelligence* adopted in 2021.[27] Policy Area 6: Gender in collaboration with the other 10 Policy Areas offers excellent recommendations.

2. International agencies, such as the OECD, World Economic Forum, UNESCO, and the World Economic Forum, support responsible AI and Robotics. **Again, we recommend an audit to see**

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[22] https://embeddedethics.seas.harvard.edu/
[23] Mozilla Foundation, Teaching responsible computing playbook, https://foundation.mozilla.org/en/what-we-fund/awards/teaching-responsible-computing-playbook/
[24] University of Buffalo, Teaching responsible computing, https://c4sg.cse.buffalo.edu/projects/Teaching%20Responsible%20Computing.html
[25] Future of Life Institute, Asilomar AI principles, https://futureoflife.org/2017/08/11/ai-principles/
[26] GPAI Paris Summit. (2021). Responsible AI working group report. Global Partnership on Artificial Intelligence. https://www.gpai.ai/projects/responsible-ai/gpai-responsible-ai-wg-report-november-2021.pdf
[27] UNESCO. (2022). *Recommendation on the ethics of artificial intelligence* (SHS/BIO/PI/2021/1), UNESCO, Paris, https://unesdoc.unesco.org/ark:/48223/pf0000381137

exactly how gender issues are treated. The UNESCO, IDB, and OECD, for example, published its *Effects of AI on the Working Lives of Women*.[28] This report tends to treat women as victims impacted by AI, not as creators of AI. This report may not look deeply enough at biases built into technology, as discussed above.

3. National governments need to regulate AI and robotics to ensure that these technologies are developed in accordance with human rights and democratic values. To do so, governments can establish an Office of Technology Assessment. **These offices need to include gender experts.** In the U.S., several members of Congress have introduced the Future of Artificial Intelligence Act bill that proposes a federal advisory committee comprised of experts from government, business, and academia to ensure the responsible development of AI and related technologies.[29] It will also be important to include gender experts.[30]

4. The private sector, consisting of universities, industries, peer-reviewed journals, and peer-reviewed conferences, should implement ethics reviews of ongoing research and new technologies. These ethics reviews should include gender.

Ethical reviews for funding. To systematically address bias in AI, a number of institutes and centers have been founded to promote socially responsible AI, including the AI Now Institute at New York University, Algorithmic Justice League, the Centre for Human-Inspired Artificial Intelligence at Cambridge University, and the Human-Centered AI Institute at Stanford University. Stanford University's Human-Centered AI Institute implemented an ethical review of all grants they fund in 2018 to check the expected cultural impacts of the proposed work. Interdisciplinary teams of lawyers, humanists, social scientists, and computer scientists judge the technical work for possible social harms.[31] This approach has yet to be evaluated.

[28] UNESCO/OECD/IDB (2022), The effects of AI on the working lives of women, UNESCO, Paris, https://doi.org/10.1787/14e9b92c-en.
[29] West, D. M., & Allen, J. R. (2020). Turning point: Policymaking in the era of artificial intelligence. Brookings Institution Press.
[30] National Academies of Sciences, Engineering, and Medicine. (2022). *Fostering responsible computing research: Foundations and practices.* Washington, DC: The National Academies Press. https://doi.org/10.17226/26507
[31] Bernstein, M. S., Levi, M., Magnus, D., Rajala, B. A., Satz, D., & Waeiss, C. (2021). Ethics and society review: Ethics reflection as a precondition to research funding. Proceedings of the National Academy of Sciences, 118(52), e2117261118.

Data reviews. Solutions to bias in AI require attention to global diversity in training data.[32] Several instruments have been developed, including "data nutrition labels," where researchers systematically label the content of training datasets.[33] Another approach, "datasheets for datasets," recommends developing metadata for machine learning datasets.[34] This latter tool considers gender and other intersectional populations.

Content Label for Machine Learning: What's in your Data?

1. Is data representative globally? What countries are represented? In what percentages?

2. Within a country, who is represented in the training data?
   Percent men/women/gender diverse/nonbinary
   Percent by ethnicity
   Percent by education, socioeconomic background, etc.

3. How is data annotated? By whom? If humans, what is their geographic location? Cultural background? Gender?

Algorithmic reviews. Solutions to bias in AI also require attention to leveraging machine learning algorithms to audit and override data bias. In many instances, such as in the case of word embeddings, where the dataset is the set of English language on the World Wide Web, bias will need to be corrected through AI audits that debias the algorithm.[35]

5. Researchers in academia or industry can implement inclusive solutions. Researchers in Denmark created a genderless voice, Q, in 2019 in efforts to remake gender norms in virtual devices.[36] Some researchers offer robots in customizable gender and skin tones. Robokind offers robots, designed for learners with autism spectrum disorder, in lighter and darker skin tones, and also modeled as a boy or a girl.[37]

6. Safety for use of sex robots. Sex robots are developing quickly. The case in favor of the use of sex robots is that they may replace prostitution and, hence, cut down on sexually transmitted diseases and, potentially, sexual violence. The case against sex robots is that they may further objectify women and others in subservient sexual roles, people may have sex without engaging in meaningful relationships, and, if robots are treated disrespectfully, that same behavior may transfer to humans.[38] Governments and appropriate international organizations should develop guidelines and laws to regulate sex robots.

Mechanical engineering: Automotive safety

The goal is to understand how gender distortions are built—sometime invisibly—into basic technologies and what can be done about it.

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[32] Zou, J., & Schiebinger, L. (2018). AI can be sexist and racist—It's time to make it fair. *Nature*, *559*(7714), 324–326. https://doi.org/10.1038/d41586-018-05707-8

[33] Chmielinski, K. S., Newman, S., Taylor, M., Joseph, J., Thomas, K., Yurkofsky, J., & Qiu, Y. C. (2022). The dataset nutrition label (2nd Gen): Leveraging context to mitigate harms in artificial intelligence. arXiv preprint arXiv:2201.03954.

[34] Gebru, T., Morgenstern, J., Vecchione, B., Vaughan, J. W., Wallach, H., Daumeé III, H., & Crawford, K. (2018). Datasheets for Datasets. arXiv:1803.09010.

[35] Zou, J., & Schiebinger, L. (2018). AI can be sexist and racist—It's time to make it fair. *Nature*, *559*(7714), 324–326. https://doi.org/10.1038/d41586-018-05707-8

[36] GenderLess Voice, https://www.genderlessvoice.com/

[37] RoboKind, https://www.robokind.com/advanced-social-robots

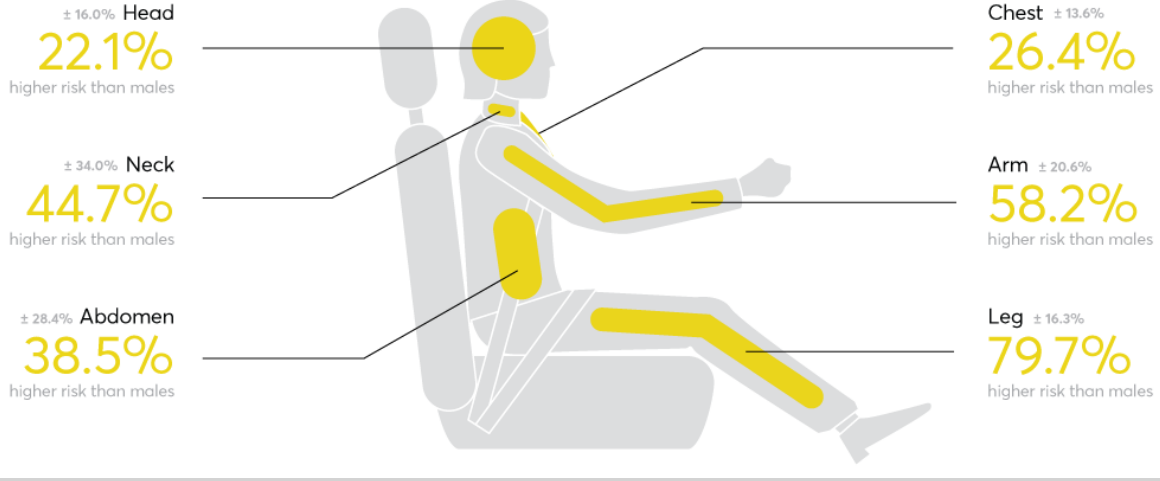
[38] Döring, N., Mohseni, M. R., & Walter, R. (2020). Design, use, and effects of sex dolls and sex robots: scoping review. *Journal of medical Internet research*, *22*(7), e18551.

Engineers establish standards and reference models for design. These standards are used educate students, generate and test hypotheses, design products, and draft legislation. Standards based on non-inclusive samples can have damaging material consequences.[39]

In automotive design, young medium-sized, able-bodied males (171 lbs.; 5′ 9″) have been taken as the norm, especially in the Global North. This means that people who do not fit this profile suffer more injuries in automobile accidents.[40] Although automobiles are marketed globally, crash test dummies, designed to promote safety, model only specific types of bodies. Experiments conducted on these models are used in designing products, drafting legislation, educating students, and generating and testing hypotheses. How cars are tested for safety among the large automakers thus impacts safety around the world.

Women suffer more serious injuries than men in automobile accidents, even when using seat belts. National U.S. automotive crash data from 1998 to 2008 revealed that the odds for a belt-restrained female driver to sustain severe injuries were 47 percent higher than those for a belt-restrained male driver involved in a comparable crash, when controlling for weight and body mass.[41]

Female Increased Risk of Injury
Estimated increase of risk for moderate injuries in a car crash compared to a male driver or right front passenger of the same age



Source: NHTSA Injury Vulnerability and Effectiveness of Occupant Protection Technologies for Older Occupants and Women. https://www.consumerreports.org/car-safety/crash-test-bias-how-male-focused-testing-puts-female-drivers-at-risk/

[39] Gendered Innovations, Rethinking Standards and Reference Models, http://genderedinnovations.stanford.edu/methods/standards.html
[40] Carter, P. M., Flannagan, C. A. C., Reed, M. P., Cunningham, R. M., & Rupp, J. D. (2014). Comparing the effects of age, BMI and gender on severe injury (AIS 3+) in motor-vehicle crashes. *Accident Analysis & Prevention*, *72*, 146–160. https://doi.org/10.1016/j.aap.2014.05.024
[41] Bose, D., Segui-Gomez, S., Maria, & Crandall, J. R. (2011). Vulnerability of female drivers involved in motor vehicle crashes: an analysis of US population at risk. *American Journal of Public Health*, *101*(12), 2368–2373. https://doi.org/10.2105/AJPH.2011.300275

Crash test dummies model the 50th percentile male body by height and weight. Dummies representing the 5th percentile female by height and weight (108 lbs.; 4′ 11″) were developed beginning in 1966, but these are only scaled-down versions of the standard, mid-sized male and do not accurately represent female anatomy and physiology. This 5th percentile dummy does not represent, for example, the average: 1) female geometry, such as the shape and form of the torso; 2) female muscle and ligament strength; 3) female spinal alignment; 4) female dynamic responses to trauma; 5) mass distribution of different body parts.[42] Researchers in Europe have developed a computer model of a 50th percentile female low severity impact dummy—the EvaRID—and a physical prototype of a 50th percentile female dummy—the BioRID 50F. But these models are not yet commercially produced for use in national automotive testing either in Europe or in the U.S.[43] For certain tests, a 5th percentile dummy is included only in the passenger seat, thereby reinforcing the stereotype that women typically don't drive.

Other populations are at risk as well. If we go beyond sex to include the intersections with age and weight, we see that some populations are particularly at risk, such as elderly women and obese men.

Elderly: Populations in many countries are aging. By 2030, over 25 percent of the populations in Europe and North America are expected to be over age 60.[44] National U.S. data show that older people are more likely to experience serious injuries in almost every crash type.[45] Older people have less dense bones and experience changes to the thorax region which increase injury risk, particularly among older women.

Obese People: The 50th percentile male dummy used in tests today represents the average height and weight of men in the late 1970s and early 1980s.[46] Today, the U.S. Centers for Disease Control classify over 40 percent of Americans as obese.[47] People with a high Body Mass Index (BMI) are more likely to suffer severe lower extremity and thorax injuries in crashes compared to people with a low BMI. Data from field tests, cadaver tests, and computational studies have shown that increased

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[42] Linder, A., & Svedberg, W. (2019). Review of average sized male and female occupant models in European regulatory safety assessment tests and European laws: Gaps and bridging suggestions. *Accident Analysis & Prevention*, *127*, 156–162. https://doi.org/10.1016/j.aap.2019.02.030

[43] Linder, A., Schick, S., Hell, W., Svensson, M., Carlsson, A., Lemmen, P., Schmitt, K.-U., Gutsche, A., & Tomasch, E. (2013). ADSEAT – Adaptive seat to reduce neck injuries for female and male occupants. *Accident Analysis & Prevention*, *60*, 334–343. https://doi.org/10.1016/j.aap.2013.02.043

[44] UN Department of Economic and Social Affairs Population Division. (2015). *Population 2030: Demographic Challenges and Opportunities for Sustainable Development Planning* (New York). https://www.un.org/en/development/desa/population/publications/pdf/trends/Population2030.pdf

[45] Carter, P. M., Flannagan, C. A. C., Reed, M. P., Cunningham, R. M., & Rupp, J. D. (2014). Comparing the effects of age, BMI and gender on severe injury (AIS 3+) in motor-vehicle crashes. *Accident Analysis & Prevention*, *72*, 146–160. https://doi.org/10.1016/j.aap.2014.05.024

[46] Schneider, L.W., Robbins, D.H., Pflüg, M.A., & Snyder, R.G. (1983). Development of anthropometrically based design specifications for an advanced adult anthropomorphic dummy family, volume 1. University of Michigan Transportation Research Institute. https://deepblue.lib.umich.edu/bitstream/handle/2027.42/259/72268.0001.001.pdf?sequence=2

[47] Hales, C. M., Margaret D. Carroll, Cheryl D. Fryar, & Cynthia L. Ogden. (2020). Prevalence of obesity and severe obesity among adults: United States, 2017–2018 (No. 360; NCHS Data Brief, p. 8). US Department of Health and Human Services, Centers for Disease Control and Prevention. https://www.cdc.gov/nchs/data/databriefs/db360-h.pdf

body mass causes obese individuals to move forward in a frontal crash, increasing the risk of injury to the thorax and the knee, thigh, and hip complex.[48]

Several digital solutions seek to overcome these problems. A virtual pregnant crash test dummy was created in 2002 by Volvo to model the pregnant body and reduce damage to fetuses.[49] In 2006, the automotive lab at the University of Michigan published the first whole-body parametric human body model for supported seated postures. These virtual models consider sex, age, height, and weight.[50] While these digital solutions are helpful, the gold standard for crash testing remains using crash test dummies, which are expensive and come in only limited models.

Recommendations:
Current automotive technologies perpetuate a cycle of discrimination and injury to people who do not fit the profile of a mid-sized white male. Automotive designers follow governmental regulations. Unless governmental motor vehicle safety standards require dynamic crash testing with average-sized female crash dummies in multiple seating positions, the dummy industry and automakers will not take action.[51]

1. Government agencies should require the use of inclusive crash test dummies. The U.S. National Highway Traffic Safety Administration (NHTSA) currently requires safety testing using dummies modeling average and small male bodies, but not 95th percentile males, elderly people, obese people, pregnant women, or mid-size female bodies.

The European New Car Assessment Programme (Euro NCAP) utilizes the same Hybrid III dummies as the U.S. NHTSA.[52] In order to obtain useful results for wider cross-sections of the population, governments should mandate vehicle safety testing using crash test dummies or simulations that represent the anatomical features of both the 50th percentile female and male, pregnant, obese, tall, and elderly bodies.

Until 2017, the Japanese National Agency for Automotive Safety (JNCAP) placed a male Hybrid III dummy in both the driver and passenger seat. In 2018, Japan adopted the small female Hybrid III dummy for the passenger seat. The Hybrid III dummy used in Japan are the same as dummies used in the U.S. and Europe, meaning that they are larger than the average Japanese body size. While this may be beneficial for the export market, it does not provide the best safety for people within Japan.[53]

In 2021, the *Furthering Advanced and Inclusive Research for Crash Tests Act* (FAIR Crash Tests Act) was introduced into a U.S. Congressional Committee. The Act would order the Government Accountability Office to evaluate NHTSA's failure to use crash test dummies that accurately represent

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[48] Hu, J., Rupp, J. D., & Reed, M. P. (2012). Focusing on vulnerable populations in crashes: Recent advances in finite element human models for injury biomechanics research. *Journal of Automotive Safety and Energy*, *3*(4), 295-307.
[49] Gendered Innovations, Inclusive Crash Test Dummies. http://genderedinnovations.stanford.edu/case-studies/crash.html#tabs-2
[50] B.D. Park, & M. Reed, Human Shapes, University of Michigan, http://humanshape.org/.
[51] Barry, K. (2019). The crash test bias: How male-focused testing puts female drivers at risk. *Consumer Reports*. https://www.consumerreports.org/car-safety/crash-test-bias-how-male-focused-testing-puts-female-drivers-at-risk/
[52] Linder, A., & Svensson, M. Y. (2019). Road safety: The average male as a norm in vehicle occupant crash safety assessment. *Interdisciplinary Science Reviews*, *44*(2), 140–153. https://doi.org/10.1080/03080188.2019.1603870
[53] NASVA, Japan, https://www.nasva.go.jp/mamoru/en/assessment_car/crackup_test.html.

the driving public while assessing vehicle safety through its 5-star safety rating program. This bill did not pass.

2. Government agencies should require a new seatbelt that does not harm fetuses. The traditional 3-point seatbelt can harm a fetus. Redesigning seatbelts to accommodate pregnancy should become a priority for automobile makers. Private developers have introduced supplementary devices to hold conventional lap belts in place, but these have not undergone rigorous government safety testing.[54] A better solution may be a redesign of the conventional 3-point seatbelt to provide greater safety for pregnant passengers.[55]

Automation

The Fourth Industrial Revolution promises that digitization, artificial intelligence, and robotics will enhance economic wellbeing. This process, however, also has the potential to displace workers. A new study, analyzing the likely impacts of automation on both women and men workers in four Latin American countries (Bolivia, Chile, Colombia, and El Salvador), shows that women face a higher risk of being displaced from their work by automation than men do.[56] These finding are consistent with those for OECD countries more generally.[57] Similar to other parts of the world, Latin American labor markets show significant gender gaps with women suffering from lower participation rates, lower wages, occupational segregation, less representation in management, and a greater threat from future automation.

At the root of these inequities lies occupational segregation. Men tend to work in management and communication; ICT; science, technology, engineering, mathematics (STEM) jobs; construction; and farming. Women tend to work in marketing, accounting, and the care sector (education, health, and domestic service). Importantly, men perform four out of five jobs expected to complement rather than be replaced by new ICT technologies, while women perform only one (those associated with the care sector). Exacerbating occupational segregation is hierarchical discrimination, in which women face barriers in accessing high-level jobs. Workers with higher education and higher skill levels face fewer risks from automation.

While the study authors found that women overall were more likely to be displaced by automation than men, they observed some variations among the countries studied. Impacts are projected to be worse for women in Bolivia, Chile, and Colombia. In El Salvador, by contrast, men are at higher risk of displacement, meaning that policy implementation may need to be tailored to the specific occupational landscape of various countries.

One fundamental problem women face is not being trained in "skills of the future," such as STEM, ICT, management and communication, and creative problem-solving tasks.[58] Women comprise, for example, only a third of workers in mathematics and computer science. This is true across Latin America more generally. A study focusing on Ecuador, Guatemala, Mexico, and Peru confirmed that

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[54] Klinich, K. (2009). Private communication.
[55] Briones Panadero, H. (2020). Analysis of the design of a car seatbelt: A study of the invention and a proposal to minimize the risk of injuries during pregnancy (Master's Thesis, Massachusetts Institute of Technology). https://dspace.mit.edu/handle/1721.1/132804
[56] Bustelo, M., Egana-delSol, P., Ripani, L., Soler, N., & Viollaz, M. (2020). Automation in Latin America: Are women at higher risk of losing their jobs? *Technological Forecasting & Social Change* 175 (2022), 1-13.
[57] Brussevich, M., Dabla-Norris, M. E., Kamunge, C., Karnane, P., Khalid, S., & Kochhar, M. K. (2018). *Gender, technology, and the future of work.* International Monetary Fund.
[58] Bustelo et al. (2022).

gender differences in types of employment exacerbate the digital divide. In addition to working in different sectors, women in these countries are less likely to be employed and are more likely to work part-time and informal jobs. These factors correlate with fewer opportunities to build digital skills through the workplace.[59]

Occupational segregation and inequalities follow gender gaps in ICT education. Equal opportunities in ICT education require mobile phone and internet access even as early as in primary school education.[60] Girls' access to mobile phone in many low- and middle-income countries (LMICs) continues to lag.[61] This is especially stark in Bangladesh, where 58 percent of women in villages do not own a mobile phone.[62] This lag leads to girls' lower rates of preparation in ICT fields of study.[63] Empowering girls to choose a career in ICT, the world's fastest-growing economic sector, could break this vicious cycle of inequality.

Even where automation has the potential to enhance the lives of girls and women, technologists often fail to understand basic infrastructures governing women's lives. Take farming in Nepal, for instance: agricultural mechanization in Nepal and elsewhere has neglected smallholder farms located in the hills and mountains, given that tractors and other farming equipment are typically designed for large flat areas. [64] At the same time, the growing remittance economy in Nepal, in which men travel abroad to earn a living, means that women are almost entirely in charge of agriculture. Studies have shown that, for religious reasons, many Hindu women are not allowed to plough the land using an ox or a bull.[65] These women would welcome automation of their work if that automation appropriately fit the infrastructures of their lives.

Even when new technological innovations in farming are suitable for women in terms of both cost and design, other factors may limit their adoption. A recent study showed how excessive weed growth limits the System of Rice Intensification (SRI), an emerging method for cultivating rice more sustainably.[66] SRI employs a light-weight weeder operated by a single person. In Bihar, India, women—particularly women from lower castes who constitute the bulk of the laboring community—have traditionally weeded in groups to avoid predatory sexual behavior and harassment. Hence, solitary weeding does not work for these women.[67] Again, technologists missed the cultural contexts within which new technologies would function.

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[59] Galperin, H., & Arcidiacono, M. (2021). Employment and the gender digital divide in Latin America: A decomposition analysis. *Telecommunications Policy*, *45*(7), 102166.
[60] Tchamyou, V. S., Asongu, S. A., & Odhiambo, N. M. (2019). The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa. *African Development Review*, *31*(3), 261-274.
[61] Zelezny-Green, R. (2018). 'Now I want to use it to learn more': using mobile phones to further the educational rights of the girl child in Kenya. *Gender & Development*, *26*(2), 299-311.
[62] Shanahan, M. (2021). *Addressing the mobile gender gap in Pakistan.* GSMA Connected Women.
[63] Hussain, K. & Siddiqa, N. (2022). Resolving gender gaps in ICT is critical for a more sustainable future, Brookings. https://www.brookings.edu/blog/education-plus-development/2022/04/27/resolving-gender-gaps-in-ict-is-critical-for-a-more-sustainable-future/
[64] Devkota, R. (2020). Responsible innovation for mechanization in hillside farming in Nepal: A gender perspective [Thesis]. University of Guelph.
[65] Ibid.
[66] Hansda, R. (2017). Small-scale farming and gender-friendly agricultural technologies: the interplay between gender, labour, caste, policy and practice. *Gender, Technology and Development*, *21*(3), 189-205. https://doi.org/10.1080/09718524.2018.1434990
[67] Ibid.

Recommendations:

1. Governments, NGOs, and researchers should employ co-creative and participatory methods when implementing new technologies. A basic method for gender and intersectional research is co-creative and participatory research, in which technologists work together with users to understand the physical requirements for a new technology alongside relevant cultural and social norms.[68] Women who work the land or carry water, for example, have knowledge of the land and its resources. They also understand their own needs and how technologies can potentially enhance their lives. Co-creative and participatory approaches typically engage users, citizens, or other stakeholders in setting research objectives, gathering and processing data, interpreting results, and implementing solutions.[69] Co-creative and participatory research typically seek to balance interests, benefits, and responsibilities between the relevant stakeholders; focus attention on user needs; and make the whole process from planning to implementation transparent and inclusive.[70]

2. Reskilling should be part of automation. Part of the budgets devoted to automation should include reskilling workers it may displace.[71]

3. Governments can forecast jobs for the future and set educational policy to meet those future needs.

Part 3. Best practices in embedding gender in tech development and equity in tech design, ensuring innovations meet the needs of women and girls

Understanding gender

Gender consists of three related dimensions—gender norms, gender identities, and gender relations—that: 1) structure societies and organizations; and 2) shape behaviors, products, technologies, environments, and knowledges.[72] Gender attitudes, behaviors, and social divisions of labor are complex, specific to particular cultures, and change across time. As stated above, it is important to understand that gender norms shape technologies and that technologies, in turn, shape gender and other social norms.

Legal gender categories: Governments typically require citizens to report their "gender" on official documents, such as birth certificates, driving licenses, and passports (most often no distinction is made between sex and gender). Numerous countries now recognize a third category. These include Argentina, Australia, Canada, Colombia, Denmark, Germany, India, Malta, Nepal, New Zealand, and Pakistan, among others, as well as many U.S. states.[73]

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[68] Gendered Innovations, Co-Creation & Participatory Methods, http://genderedinnovations.stanford.edu/methods/co-creation.html

[69] Gonsalves, J., Becker, T., Braun, A., Campilan, D., de Chavez, H., Fajber, E., Kapiriri, M., Rivaca-Caminade, J., & Vernooy, R. (2005). *Participatory research and development for sustainable agriculture and natural resource management: A sourcebook, Volume 1: Understanding participatory research and development.* Ottawa: International Development Research Centre (IDRC).

[70] Center for Indigenous Peoples' Nutrition and Environment. (2003). *Indigenous peoples & participatory health research*. World Health Organization. https://www.mcgill.ca/cine/files/cine/partreresearch_english.pdf

[71] Illanes, P., Lund, S., Mourshed, M., Rutherford, S., & Tyreman, M. (2018). Retraining and reskilling workers in the age of automation. *McKinsey Global Institute*.

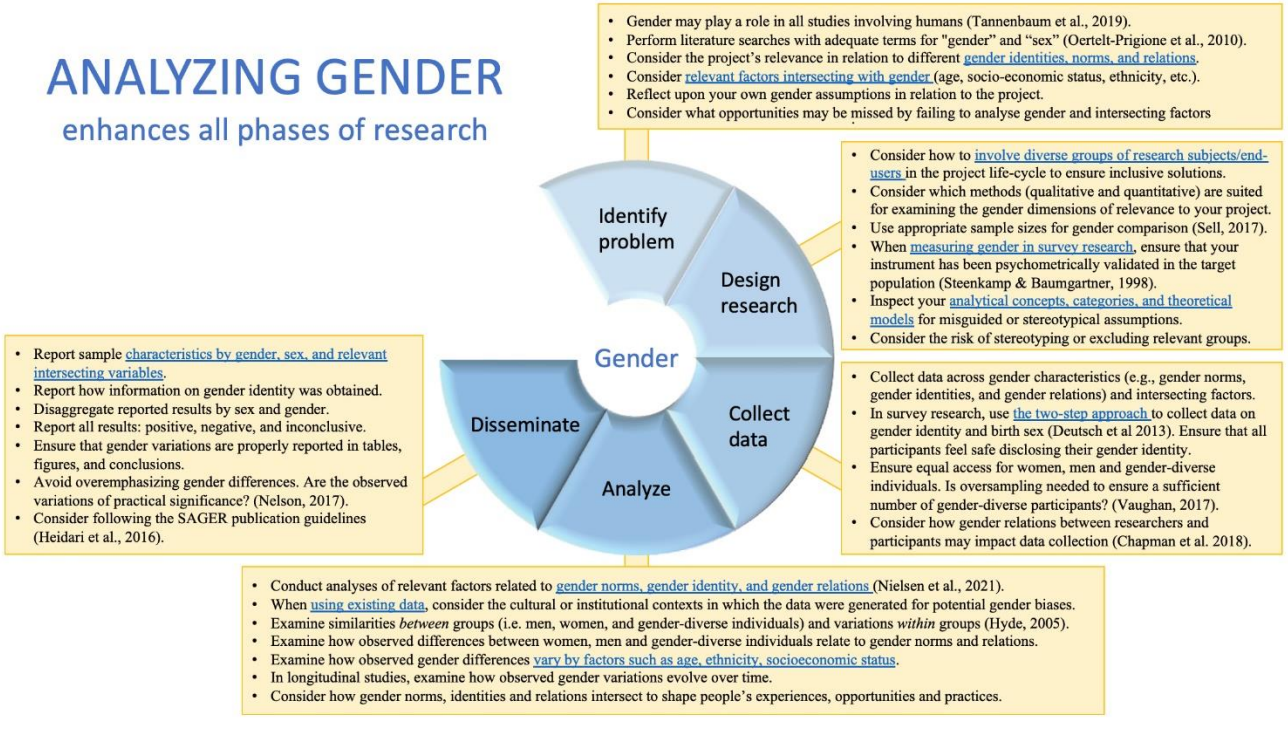
[72] Gendered Innovations, Terms, Gender, http://genderedinnovations.stanford.edu/terms/gender.html

[73] Fung, K. (2021). Which countries recognize third gender option on passports? *Newsweek*. https://www.newsweek.com/which-countries-recognize-third-gender-option-passports-1643167

Gender is multi-dimensional: Gender is often described as existing on a masculinity-femininity spectrum, but such categories typically reinforce stereotypes about women and men, and ignore individuals who fall outside these traditional gender binaries.[74] Gender is multidimensional: any given individual may experience any configuration of gender norms, identities, and relations.

Methodology to integrate sex, gender, and intersectional analysis into technology

Sex, gender, and intersectional factors influence all stages of research, from strategic considerations for establishing priorities and building theory to more routine tasks of formulating questions, designing methodologies, and interpreting data. Many pitfalls can be avoided—and new ideas or opportunities identified—by designing, sex, gender, and intersectional analysis into research from the start.



Source: Gendered Innovations, Methods, Analyzing Gender, http://genderedinnovations.stanford.edu/methods/gender.html

Methods for sex, gender, and intersectional analysis flow through the entire research process[75]:

Rethinking Research Priorities and Outcomes
Rethinking Concepts and Theories
Formulating Research Questions
Analyzing Sex

[74] Nielsen, M.W., Peragine, D., Neilands, T. B., Stefanick, M.L., Ioannidis, J. P. A., Pilote, L., Prochaska, J. J., Cullen, M. R., Einstein, G., Klinge, I., LeBlanc, H., Paik, H. Y., Risvedt, S., & Schiebinger, L. (2021), Gender-Related Variables for Health Research. *Biology of Sex Differences, 12(1),* 1-16.

[75] Gendered Innovations, Methods, http://genderedinnovations.stanford.edu/methods-sex-and-gender-analysis.html

Intersectionality

Analyzing gender alone is not enough. Gender norms intersect with a variety of other social factors, as we have seen in a number of examples in section two above. Intersectionality describes overlapping or intersecting forms of discrimination related to gender, sex, ethnicity, age, socioeconomic status, caste, sexuality, geographic location, migration status, religion, and race, among other factors. The term was coined in 1989 by legal scholar Kimberlé Crenshaw to describe how multiple forms of discrimination, power, and privilege intersect in Black women's lives, in ways that are erased when sexism and racism are treated separately.[76] In 1989, her concern was that the white feminist movement was excluding women of color.

Since 1989, the term has been expanded to describe intersecting forms of oppression and inequity emerging from structural advantages and disadvantages that shape a person's or a group's experience and social opportunities.[77]

Axes of discrimination differ by culture; these may include:

Age/Life Stage	Migration Status
Caste	Race
Disabilities	Religious Culture
Ethnicity	Sex
Educational Background	Sexual Orientation
Gender	Socioeconomic Status
Geographic Location	Sustainability
Handedness	…and many others
Language	

From the very beginning, technologists need to consider the many axes of discrimination and delineate those most relevant to their research. Important questions are: Who will this technology benefit, and who might it harm or leave out? How can the benefits be equitable?

Data collection

Governments, agencies, and researchers collect data that asks for sex and/or gender. UN forms, for example, ask for "gender" and offer two options: "male" and "female." Male and female are terms that apply to biological sex, not sociocultural gender.

For humans, data may be collected for sex.[78]

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[76] Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics, *University of Chicago Legal Forum* Vol. no. 1, 139-167.

[77] Gendered Innovations, Terms, Intersectionality, http://genderedinnovations.stanford.edu/terms/intersectionality.html

[78] PhenX Toolkit, phenxtoolkit.org

What was your biological sex assigned at birth? With these options:

- [ ] Female
- [ ] Male
- [ ] Intersex
- [ ] None of these describe me (optional free text)
- [ ] Prefer not to answer

For humans, data may be collected for gender. Categories of collection will depend on the culture. Terms relevant to many parts of North America, Europe, Australia, and parts of South America, may include:

- [ ] Man
- [ ] Woman
- [ ] Non-binary
- [ ] Transgender
- [ ] None of these describe me, and I'd like to consider additional options
- [ ] Prefer not to answer

Depending on the purpose of the question, a branching logic may be implemented. If 'non-binary', 'transgender,' or 'none of these describe me and I'd like to consider additional options' selected:

Are any of these a closer description to your gender identity?

- [ ] Trans man/Transgender Man/FTM
- [ ] Trans woman/Transgender Woman/MTF
- [ ] Genderqueer
- [ ] Genderfluid
- [ ] Gender variant
- [ ] Questioning or unsure of your gender identity
- [ ] None of these describe me, and I want to specify_____

Recommendation: Governmental, employment, education, health, and other required forms must collect data intentionally, asking either for sex and/or gender with culturally appropriate collection categories. The U.S. National Academies of Sciences, Engineering, and Medicine have just issued data collection guidelines.[79]

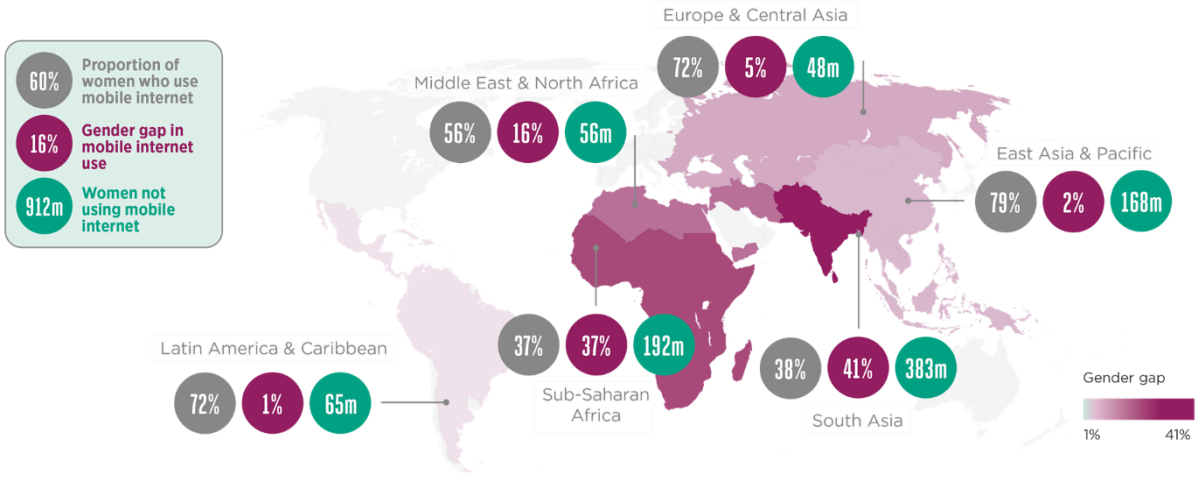
Part 4. Barriers and pathways for adopting human rights-based technology that prevent discrimination, bias, violence, and privacy breaches

The transformational potential of internet access is not equally distributed. Of the estimated 2.9 billion people currently unconnected, the majority are women and girls, and most live in LMICs.[80] A strong link persists between internet access and future ICT or STEM employment. GSMA, an industrial group, reported that the mobile internet gender gap has narrowed from 25 percent in 2017 to 15

[79] National Academies of Sciences, Engineering, and Medicine. (2022). *Measuring Sex, Gender Identity, and Sexual Orientation*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26424.
[80] OECD. (2018). Bridging the digital gender divide: include, upskill, innovate.

percent in 2020. Yet, women are still 15 percent less likely than men to use mobile internet, meaning that 264 million fewer women than men have access to the internet.[81]

Gender gap in mobile internet use in LMICs, by region



Source: Connected Women. (2019). *The Mobile Gender Gap Report*. GSMA. https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/GSMA-The-Mobile-Gender-Gap-Report-2019.pdf

A gender gap persists also in cybercrime. Thirty-five percent of women do not feel safe online, in comparison to 27 percent of men. Nearly half of women have had their social media accounts hacked, compared to about a third of men. Identity theft is also a problem, as women are twice as likely as men to have their identities stolen. These experiences are often intensified for Black people, Indigenous people, and people of color.[82] Some 156 countries (80 percent) have enacted cybercrime legislation with the highest adoption rate (91 percent) in Europe and the lowest (72 percent) in Africa.[83]

Facial Recognition

In the equity and human rights space, facial recognition is iconic for demonstrating how intersectional approaches to research leads to technological advances. In pathbreaking work, technologists Joy Boulamwini and Timnit Gebru analyzed intersectionality in facial recognition—specifically how gender and race intersect. Their approach reveals that facial recognition often fails to "see" Black women's faces. Their **gender** analysis shows that systems performed better on men's faces than on women's faces. Their **race** analysis shows that systems performed better on individuals with lighter

[81] Connected Women. (2019). *The mobile gender gap report*. GSMA. https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/GSMA-The-Mobile-Gender-Gap-Report-2019.pdf

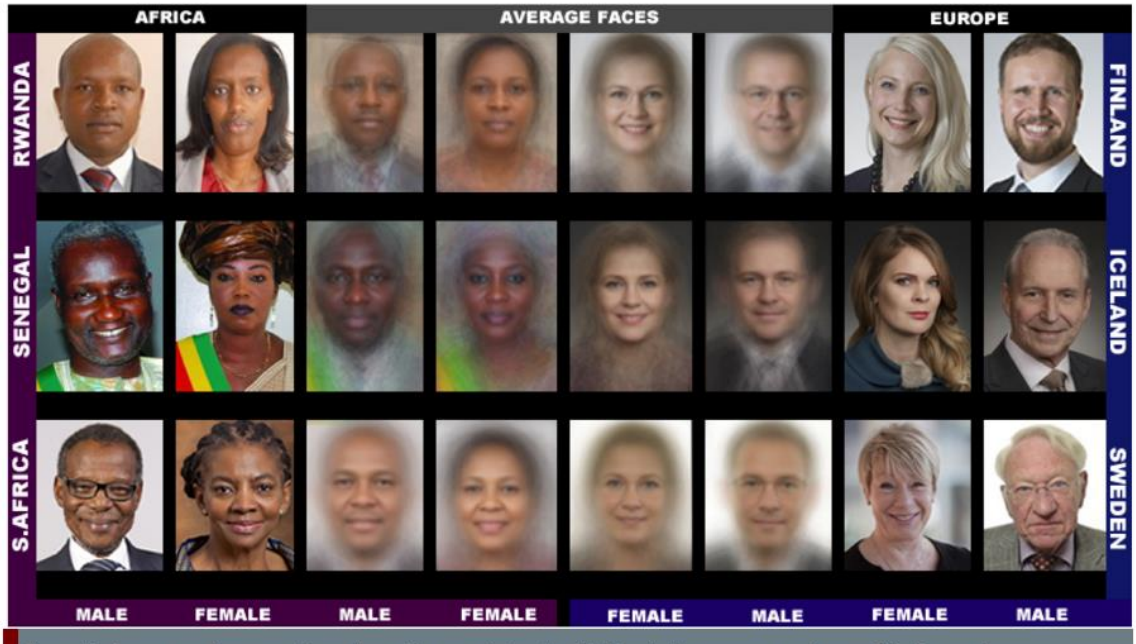
[82] Malwarebytes, Demographics of cybercrime report, https://www.malwarebytes.com/resources/2021-demographics-of-cybercrime-report/index.html#:~:text=Key%20takeaways%20from%20the%20report%3A&text=50%20percent%20of%20people%20do,to%2027%20percent%20of%20men

[83] UNCTAD, Cybercrime legislation worldwide, https://unctad.org/page/cybercrime-legislation-worldwide

skin tones than those with darker skin tones. Based on this **intersectional** analysis, they demonstrated that facial recognition performed worst for Black women users.[84]

The analysis has subsequently been extended to include **sexuality:** Systems can often not "recognize" transgender faces, especially during transition periods.[85] And further **gender** analysis reveals that facial cosmetics reduce the accuracy facial recognition methods by up to 76.21 percent.[86]

Boulamwini and Gebru's intersectional innovation was to create a more inclusive dataset that included faces from women and men of darker and lighter skin. They chose Members of Parliament from six countries—three in Africa and three in Europe. This, however, does not solve the problem of global representation. This new dataset does not include Asians or Indigenous peoples from the Americas or Australia. Nor it is labelled in a way that we can tell if any non-binary people are included.



Example images and average faces from the new dataset, which includes women and men of darker and lighter skin drawn from Members of Parliament form six countries. Buolamwini & Gebru, 2018, with permission.

Source: Buolamwini, J., & Gebru, T. (2018). Gender shades: Intersectional accuracy disparities in commercial gender classification. *Proceedings of Machine Learning Research, 81*, 77-91.

Recommendations:
Facial recognition has also become an iconic example of a useful technology that has been found to breach privacy and to be use for unwanted surveillance.

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[84] Buolamwini, J., & Gebru, T. (2018). Gender shades: Intersectional accuracy disparities in commercial gender classification. *Proceedings of Machine Learning Research, 81*, 77-91.
[85] Keyes, O. (2018). The misgendering machines: trans/HCI implications of automatic gender recognition. *Proceedings of the ACM on Human-Computer Interaction,* (CSCW). https://doi.org/10.1145/3274357
[86] Dantcheva, A., Chen, C., & Ross, A. (2012). Can facial cosmetics affect the matching accuracy of face recognition systems? *2012 IEEE Fifth International Conference on Biometrics: Theory, Applications and Systems (BTAS)*, (pp. 391-398). IEEE. https://ieeexplore.ieee.org/document/6374605/

1. Governments, municipalities, educational institutions, and employers should consider proper use and potential misuse of technologies. Facial recognition can be useful for opening smart phones, allowing quick passage across international borders, and more. Facial recognition, however, has the potential for bias, errors, and misuse. In the U.S., use of facial recognition by law enforcement has led to high levels of false arrests of Black men.[87] In China, citizen surveillance has been used to produce a "social credit score" that can falsely ban people from travel, exclude them from schools, or restrict access to government jobs.[88] These issues have led to several actions: Belgium and Morocco have banned the public use of facial recognition completely, France and Sweden have expressly prohibited it in schools, and San Francisco, California, has banned its use by local agencies like the transport authority or law enforcement. Companies, too, are pulling back: IBM has left the facial recognition business entirely, and Amazon, in response to worldwide protests against systemic racial injustices in 2020, has stopped police from using its facial recognition technology.[89]

2. Create governmental offices to regulate facial recognition. Seeking long-term solutions, the U.S. Algorithmic Justice League, founded by Buolamwini, has called for the creation of a federal office similar to the U.S. FDA to regulate facial recognition.[90] Understanding underlying intersectional discrimination in society can help researchers develop more just and responsible technologies.

Biometrics

In addition to ensuring the transparency and safety of biometric programs, it is crucial to consider the infrastructure through which biometric data is acquired. In 2015, the government of Bangladesh launched a mandatory program collecting the fingerprints of every person who owned a mobile SIM card.[91] This law was criticized for increased citizen surveillance and for undermining free speech. Importantly, the biometric SIM registration also potentially reduced women's access to phones. According to one ethnographic study, some women had previously registered for a SIM card using a male name to avoid gender-based harassment over the phone. Other women, due to social and religious norms governing behavior, did not want to go through the biometric registration process, as a male staff member would ostensibly have to touch their hands to take their fingerprints. In addition to ensuring the protection of sensitive biometric data, governmental agencies should consider how gendered behavioral norms impact women's use of technology.

Recommendation:
Policy makers should ensure that biometric programs undergo thorough and transparent civil rights assessment prior to implementation, with special attention to gender issues.

Part 5. How to leverage technology to promote women's voice, agency, and participation

[87] Perkowitz, S. (2021). The bias in the machine: Facial recognition technology and racial disparities.
[88] West, D. M., & Allen, J. R. (2020). Turning point: Policymaking in the era of artificial intelligence. Brookings Institution Press.
[89] Surfshark. https://surfshark.com/facial-recognition-map
[90] Learned-Miller, E., Ordóñez, V., Morgenstern, J., & Joy Buolamwini, J. (2020). Facial recognition technologies in the wild. https://global-uploads.webflow.com/5e027ca188c99e3515b404b7/5ed1145952bc185203f3d009_FRTsFederalOfficeMay2020.pdf.
[91] Ahmed, S. I., Haque, M. R., Guha, S., Rifat, M. R., & Dell, N. (2017). Privacy, security, and surveillance in the Global South: A study of biometric mobile SIM registration in Bangladesh. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 906-918). https://doi.org/10.1145/3025453.3025961

Reproductive health

Technology can improve women's and children's health in rural and underprivileged regions. mMitra is a free mobile call service provided by Armman Foundation that operates in nine states in India. The app sends women enrolled in the program preventive care information in their chosen language on a regular basis to help them through pregnancy and early infant care. To date, the foundation reports that their program has benefitted 2.9 million women in slum communities. The reported impacts include: an increase in women's knowledge of family planning methods, an increase in the number of pregnant women who take prenatal vitamins, and an increase in proportion of infants under six months who were exclusively breastfed.[92]

The Reproductiva app, launched in 2018 in Timor-Leste helps adolescent men and women obtain high-quality information about sex and reproduction. Almost a quarter of all girls in Timor-Leste have a child before turning 20. This high rate of teenage pregnancy is driven by a lack of knowledge among adolescents about what leads to pregnancy, local taboos about sex and reproduction, lack of access to modern forms of contraception, and young women's lack of power in sexual relationships. The Reprodutiva app provides young people in Timor-Leste access to information about sexual and reproductive health from professionals, offers group chats for information sharing, and helps set up medical appointments.[93]

FemTech

Women file only 13 percent of patents in the U.S. Rem Koning at Harvard Business School has estimated that if all biomedical patents filed between 1976 and 2010 had been produced equally by men and women, there would be some 6500 more female-focused biomedical inventions— which could have led to more biotechnologies that benefit women.[94]

We are beginning to see the benefits of the FemTech revolution. "FemTech" refers to "software, diagnostics, products, and services that use technology to focus on women's health."[95,96] The term was coined in 2016 by Ida Tin, the Danish-born founder of Clue, a period and ovulation tracking app established in Germany in 2013.[97] FemTech covers a wide range of issues related to women's health. Loss of productivity resulting from improperly treated health issues experienced by women working in Japan, for example, is estimated at ¥2.7 trillion (U.S. $20 billion). Menopause can raise difficult issues. In Japan, women may refuse promotions to management position because of anxiety about symptoms associated with menopause, meaning that women miss out on leadership positions.[98] Deploying consumer-centric solutions can enable future women leaders.

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[92] Armman Foundation, https://armman.org/programmes/

[93] Plan International, Health app helps teens avoid pregnancy, https://plan-international.org/case-studies/health-app-helps-teens-avoid-pregnancy/

[94] Koning, R., Samila, S., & Ferguson, J. P. (2021). Who do we invent for? Patents by women focus more on women's health, but few women get to invent. *Science*, *372*(6548), 1345-1348.

[95] Wiederhold, B. K. (2021). Femtech: Digital help for women's health care across the life span. *Cyberpsychology, Behavior, and Social Networking*, *24*(11), 697–698. https://doi.org/10.1089/cyber.2021.29230.editorial

[96] Faubion, S. (2021). Femtech and midlife women's health: good, bad, or ugly? *Menopause*, 28 (4), 347-348. doi: 10.1097/GME.0000000000001742.

[97] FemTech Live. (2021). FemTech Founder: An interview with Clue CEO, Ida Tin. *FEMTECH.LIVE*. https://femtech.live/femtech-founder-an-interview-with-clue-ceo-ida-tin/

[98] Tech4Eva. (2021). FemTech and Japan, a land of opportunities, *Tech4Eva*. https://www.tech4eva.ch/post/femtech-and-japan-a-land-of-opportunites

And FemTech is taking off.[99] In 2021, the New York Times reported that the industry in the U.S. generated over $820 million in global revenue. In Japan the FemTech market grew from ¥57.5 billion (U.S. $428 million) in 2019 to almost ¥60 billion (U.S. $448 million) in 2020. Overall, Asia accounts for only eight percent of the world's FemTech companies, compared to North America's 55 percent.

The goal of much of FemTech is better treatments for women and greater gender equity in the healthcare system. Take Evvy, a U.S. startup that provides at-home vaginal microbiome tests. People with vaginas suffer from infections and discomfort that often go mis- or undiagnosed. Evvy helps by allowing people to balance their vaginal microbiome to avoid infections and discomfort. The vaginal microbiome is defined as the complex ecosystem of microorganisms, including bacteria and fungi, that lives inside the vagina. Through home testing, Evvy can both provide better care for those who are suffering from recurrent infections. Their future goals include providing treatment to help users balance their vaginal microbiome at home, putting the power to improve their health in their own hands.[100]

In Japan, Ring Echo is a new technology developed by Lily MedTech to detect breast cancer and to replace the mammogram, a test which many people with breasts find extremely painful. The Ring Echo system is designed to be highly accurate and painless. An examinee lies facedown on a bed-type device and puts their breast into a hole filled with water. The ring-type ultrasonic transducer then moves up and down, taking a three-dimensional scan of the breast by producing sound waves that bounce off body tissue. This test, performed by a technician or a nurse, requires no additional specialized skills.[101]

Some criticize FemTech for excluding trans and non-binary people not born biologically female. Queerly Health is one startup exclusively dedicated to the lesbian, gay, bisexual, transgender, queer or questioning, plus others that might include intersex, asexual, two-spirited, or others (LGBTQ+) and trans community. It allows participants in the U.S. to book LGBTQ+ friendly health and wellness practitioners digitally. Another startup, Plume, provides gender-affirming hormone replacement therapies and medical consultations tailored to the trans community.[102] In Berlin, Germany, Clue, the original FemTech company, defines its work as focused on "women and people with cycles." It has also developed a focus on LGBTQ+ health.[103]

Solar Sisters

Solar Sisters provides access to energy, jobs, environmental sustainability. Solar sisters provide skill training to impoverished women in rural Africa to sell clean, renewable energy. In doing so, Solar Sisters provides communities with clean, affordable, renewable energy while helping rural women

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[99] McKinsey & Company. (2022). The dawn of the FemTech revolution. https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/the-dawn-of-the-femtech-revolution

[100] Evvy, https://www.evvy.com/

[101] University of Tokyo, Gently sounding out breast cancer, https://www.u-tokyo.ac.jp/focus/en/features/entrepreneurs05.html

[102] Agarwal, P. (2021). "Femtech" is booming—But does it really make healthcare more equal? *Prospect Magazine*. https://www.prospectmagazine.co.uk/science-and-technology/femtech-is-booming-but-does-it-really-make-healthcare-more-equal

[103] Laura Lovett. (2020). Clue's first CMO, Dr. Lynae Brayboy, talks fertility tech, LGBTQ health, the clinical trial gender gap. *MobiHealthNews*. https://www.mobihealthnews.com/news/clues-first-cmo-dr-lyane-brayboy-talks-fertility-tech-lgbtq-health-clinical-trial-gender-gap

find jobs and, thus, financial freedom.[104] Since 2010, Solar Sister has supported over 7,000 entrepreneurs, distributed over 647,250 clean energy products, and reached 3 million people.

Solar Sisters is now expanding into rural Brazil. The goals in Brazil are similar to those in Africa: to empower women by giving them economic resources and know-how to promote clean energy. The goal is to promote clean energy in communities to improve family standards of living, self sufficiency, and to overcome gender and income disparities. Solar power has the potential to fulfill basic needs: for example, 4.4 percent of Brazilian household (9 million people) do not have access to clean fuels and technologies for cooking.[105]

Recommendations:

1. Bring greater gender parity to entrepreneurship by increasing access to financing for women. In the U.S., in 2019 only 2.8 percent of funding went to women-led startups. Only about 0.2 percent goes to Black women. Industry solutions include venture capital companies, such as the U.S. firm Backstage Capital, that invests in women and people of color.[106]

2. Governments can invest in schemes that benefit women, especially rural women. Australia's National Broadband Network (NBN) has provided fast broadband connection that supports working from home, accessing education, and starting businesses. The effects were found to be particularly strong in rural areas and for women: across the 2010s, the number of self-employed women grew at an average 2.3 percent every year, compared to only 0.1 percent on average in non-NBN areas.[107]

3. Multi-stakeholder partnerships can provide loan guarantees for women entrepreneurs.

4. Governments and industry can create accelerators for early-stage startups founded by women. Accelerators offer mentorship, financial support, and access to talent startups can hire.[108]

Menstrual products

Can a change in menstrual products help achieve the UN's SDGs #1 "no poverty," #3 "good health & well-being, #5 "gender equality," and #6 "clean water and sanitation" by the year 2030? Can we promote two social goods: gender equity and environmental sustainability?

Typical menstrual products, such as single-use tampons and pads, pollute. Some 20 billion disposable menstrual products are discarded each year in the U.S. alone, generating 240,000 tons of solid waste, thus 0.1 percent of the U.S. total municipal solid waste generated in 2018.[109] In addition, consumers spend U.S. $26 billion globally on these throw-away products. This means that both the economic and environmental cost of these products is high.

Novel campaigns are addressing both the environmental impact of menstruation and "period poverty," or the struggle many face to afford good-quality menstrual products particularly in LMICs. Menstrual

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[104] Solar Sisters, https://solarsister.org/

[105] Cañas, B., Ceron, J., & Solodka, Y. (2020). *Solar Sister International* [MSc, Barcelona School of Management and ESCI UPF]. https://repositori.upf.edu/bitstream/handle/10230/45590/MScIB2020Solar.pdf?sequence=1&isAllowed=y

[106] McKinsey & Company, Intersection newsletter, https://www.mckinsey.com/~/media/mckinsey/email/intersection/2022/05/12/2022-05-12b.html

[107] NBN (2018), Connecting Australia, National Broadband Network Australia.

[108] Hathaway, I. (2016). What startup accelerators really do. *Harvard Business Review, 1*.

[109] Fourcassier, S., Douziech, M., Perez-Lopez, P., Schiebinger, L. Menstrual Products: A Comparable Life Cycle Assessment, *Cleaner Environmental Systems*, forthcoming.

products can be prohibitively expensive in low-income settings, such as parts of the U.S., sub-Saharan Africa, and rural India. As a result, people may use reusable cloth and newspapers, or simply stay home.[110]

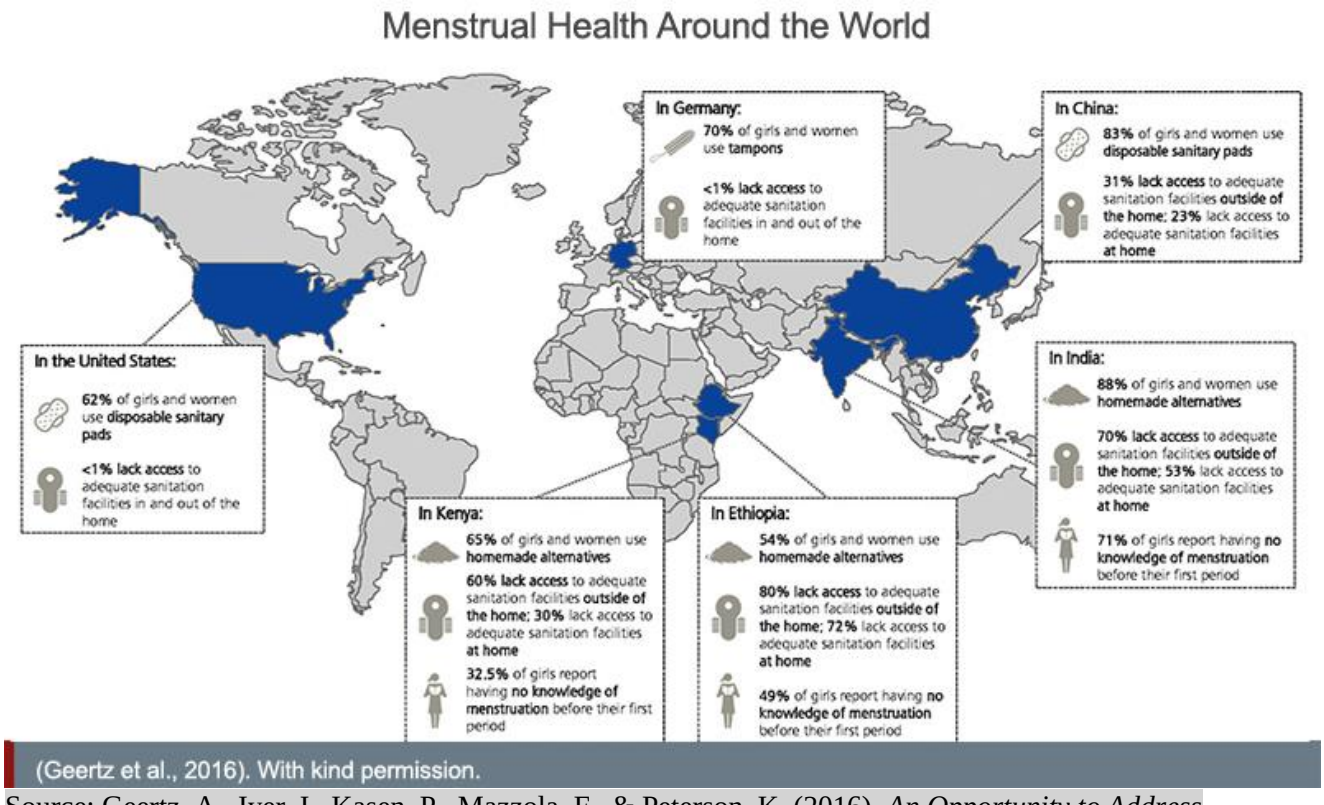
Access to reliable products can improve girls' school attendance, which can help narrow the gender gap in ICT. Several recent projects have studied the impact of introducing menstrual cups to school-age children in South Africa, Uganda, Kenya, and rural India. Participants were provided a cup and, equally important, education on menstruation and cup use, and a bar of soap each month, plus information on how to disinfect cups (although many lacked the simple equipment and water required to boil cups).[111] Studies found that, with proper education and training, participants successfully used the cups, and often preferred them to pads.[112] These products—when coupled with education tools, like the Raaji chatbot developed by a social enterprise in Pakistan to disseminate educational content surrounding menstrual products to schools in rural areas—can work to ensure both gender equity and environmental sustainability.[113]

[110] Sommer, M., & Sahin, M. (2013). Overcoming the Taboo: Advancing the Global Agenda for Menstrual Hygiene Management for Schoolgirls. *American Journal of Public Health*, *103*(9), 1556–1559. https://doi.org/10.2105/AJPH.2013.301374

[111] Hyttel, M., Thomsen, C. F., Luff, B., Storrusten, H., Nyakato, V. N., & Tellier, M. (2017). Drivers and challenges to use of menstrual cups among schoolgirls in rural Uganda: A qualitative study. *Waterlines*, *36*(2), 109–124; Beksinska, M. E., Smit, J., Greener, R., Todd, C. S., Lee, M. T., Maphumulo, V., & Hoffmann, V. (2015). Acceptability and performance of the menstrual cup in South Africa: A randomized crossover trial comparing the menstrual cup to tampons or sanitary pads. *Journal of Women's Health (2002)*, *24*(2), 151–158. https://doi.org/10.1089/jwh.2014.5021; Mason, L., Laserson, K. F., Oruko, K., Nyothach, E., Alexander, K. T., Odhiambo, F. O., Eleveld, A., Isiye, E., Ngere, I., Omoto, J., Mohammad, A., Vulule, J., & Phillips-Howard, P. A. (2015). Adolescent schoolgirls' experiences of menstrual cups and pads in rural western Kenya: A qualitative study. *Waterlines*, *34*(1), 15–30.

[112] Howard, C., Rose, C. L., Trouton, K., Stamm, H., Marentette, D., Kirkpatrick, N., Karalic, S., Fernandez, R., & Paget, J. (2011). FLOW (finding lasting options for women): Multicentre randomized controlled trial comparing tampons with menstrual cups. *Canadian Family Physician Medecin De Famille Canadien*, *57*(6), e208-215;

[113] Ask Raaji, https://auratraaj.co/



Source: Geertz, A., Iyer, I., Kasen, P., Mazzola, F., & Peterson, K. (2016). *An Opportunity to Address Menstrual Health and Gender Equity.* FSG.

Recommendations:

1. Governmental and nongovernmental organizations can address "period poverty" in ways that promotes both gender equity and environmental sustainability. Many countries tax period products as "non-essential items," thereby increasing the price of these necessary goods. Countries can work to improve gender equity by exempting these products from taxation—or even making the products free to everyone, as Scotland has now done.[114] However, it is critical to address this social issue in environmentally sustainable ways. It will be important for these free products to be sustainable by offering period underwear, menstrual cups, and reusable pads.

2. "Period Poverty" needs to be addressed in culturally sensitive ways. Although menstrual cups often reduce the fear of leaking and encourage independence, cultural taboos against the use of internal products in various countries may impede their adoption. Further, the lack of running water and private bathrooms at some schools may mean that it is difficult to clean cups in a sanitary way.[115] Governments and NGOs must consider the cultural and logistical context of introducing new products when addressing period poverty. Further, governments and NGOs need to provide "accurate and timely rights-based education about menstruation" to educate users about novel products, as UNESCO has urged.[116]

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[114] Rodriguez, L. (2021). 20 places around the world where governments provide free period products. *Global Citizen.* https://www.globalcitizen.org/en/content/free-period-products-countries-cities-worldwide/

[115] Kuncio, T. (2018). Pilot Study Findings on the Provision of Hygiene Kits with Reusable Sanitary Pads" (Mbarara: UNHCR - Mbarara Sub-Office).

[116] Harrison, M. E., & Tyson, N. (2022). Menstruation: Environmental impact and need for global health equity. *International Journal of Gynecology & Obstetrics*. 1–5. DOI: 10.1002/ijgo.14311

3. When disposable pads are deemed necessary, organizations must work to lessen the environmental impact of the products. Governments, NGOs, and manufacturers should work with local materials and producers to make pads that benefit both the economy and the environment. For instance, the SHE28 social enterprise campaign in Rwanda has launched a menstrual pad made with banana fiber, a product typically disposed of during the banana farming process. The campaign provides farmers with both the tools and training to extract the fiber and then purchases the fiber to make disposable pads which are almost entirely biodegradable. This endeavor serves to benefit both the banana farms and the users of the pad, as well as lessen the environmental impact of single-use menstrual goods.

4. Industry can do life-cycle assessments of their products and make this information available to consumers. Environmental impact information should be transparent on packaging to offer consumers an opportunity to choose the most sustainable product. Life-cycle assessments analyze the environmental impacts of a product throughout its life cycle from growing, extracting, and processing raw materials, manufacturing, transportation and distribution, and recycling or final disposal. A recent study compared the sustainability of seven menstrual products across three countries, France, India, and the U.S. The menstrual products were: disposable pads (organic and non-organic), tampons (organic and non-organic), reusable pads, menstrual cups, and menstrual underwear. They were analyzed across eight environmental factors, including land use, water use, energy, the likelihood of cancer risk, the likelihood of water acidification, etc. The results show that reusable menstrual cups are the most sustainable option, with the lowest impact score across all indicators and countries. Menstrual underwear ranked second, given their double functions as underwear and menstrual absorbent. Reusable pads ranked third lowest.[117]

5. Industry can produce inclusive products. Some companies make gender-inclusive period underwear designed for gender-non-conforming people, such as trans men. Companies have also expanded menstrual underwear to include a line of "nude" underwear that come in five-varying shades.[118]

Part 6. How to measure the impact of technology and innovation on women and girls and improve accountability systems

A number of new studies demonstrate the correlation between *who* does S&T and *what* S&T is done. This is important, and governments, funding agencies, NGOs, and industry need to appreciate the urgency of this matter. As we have known for decades, women and people of color are underrepresented in S&T. In the U.S., for example, women represent 28.4 percent of the scientific workforce, and this percentage varies by domain, with a high of 72.8 percent in psychology and a low of 14.5 percent in engineering.[119]

Inclusive teams; methodologies that integrate sex, gender, and intersectional analysis into research design; and the willingness to fund new topics all enhance the excellence and social relevance of

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[117] Fourcassier, S., Douziech, M., Perez-Lopez, P., Schiebinger, L. Menstrual Products: A Comparable Life Cycle Assessment, *Cleaner Environmental Systems,* 7 (2022), 1-8.
[118] Arlexis, S. (2018). What's In TomboyX's Nude Underwear Line? It's The Inclusive Collection You Always Needed. *Bustle*. https://www.bustle.com/p/whats-in-tomboyxs-nude-underwear-line-its-the-inclusive-collection-you-always-needed-9107046
[119] U.S. National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering* (Tech. Rep. NSF 17-310, National Center for Science and Engineering Statistics, Arlington, VA).

S&T.[120] In the field of medicine, Nielsen et al.'s study of 1.5 million papers found a link between women's authorship and the likelihood of a study including gender and sex analysis, thus demonstrating the mutual benefits of promoting both the scientific advancement of women and the integration of gender and sex analysis into medical research.[121] In the discipline of History, demographic diversity in researchers has sparked discovery and innovation in research. Specifically, the growth in women historians led to the broadening of research agendas to include gender history and an increased sensitivity to numerous new topics and methodologies in the field.[122] In biomedicine, patents reveal that women innovators create more female-focused biomedical inventions (as discussed in relation to FemTech above).[123] Across scientific disciplines, a U.S. study revealed that authors from minority groups (gender, ethnic, etc.) tend to publish on research topics that reflect their social identities.[124] In short, including women and minority groups in the creation of S&T enhances S&T and better serves societies.

Recommendations:

1. The World Economic Forum's Global Gender Gap Report should be expanded to include measures for gender equality on S&T research teams AND the inclusion of sex, gender, and intersectional analysis in S&T research design. This reporting needs to address both *who* does S&T and *what* S&T is done. Current subindices include: economic participation and opportunity, educational attainment, health and survival, and political empowerment. A S&T subindex should measure: participation in S&T disaggregated by gender, patents disaggregated by gender, S&T research funding disaggregated by gender, research agendas disaggregated by author gender, and, importantly, discovery and innovation produced by integrating sex, gender, and/or intersectional analysis into S&T research design.

2. World Economic Forum's Global Gender Gap Report should be expanded to include measures for entrepreneurship. These would include funding for entrepreneurs disaggregated by gender and for innovations that benefit women and girls.

3. Gender Impact Assessment should be implemented.[125] Gender Impact Assessment (GIA) is a stepwise process designed to evaluate the potential *impacts* of research before research decisions are finalized. The goal is for experts to provide evidence-based recommendations for research redesign—in the *development* phase. GIA is a technique aligned with the principles of Responsible Research Innovation (RRI) and the UN SDGs.[126]

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[120] Tannenbaum, C., Ellis, R. P., Eyssel, F., Zou, J., & Schiebinger, L. (2019). Sex and gender analysis improves science and engineering. *Nature*, *575*(7783), 137–147. https://doi.org/10.1038/s41586-019-1657-6

[121] Nielsen, M.W., Andersen, J.P., Schiebinger, L., Schneider, J.W. (2017). One and a half million medical papers reveal a link between author gender and attention to gender and sex analysis. *Nature Human Behaviour*, 1(11):791-796.

[122] Risi, S., Nielsen, M.W., Kerr, E., Brady, E., Kim, L., McFarland, D.A., Jurafsky, D., Zou, J. & Schiebinger, L. (2022). Diversifying history: A large-scale analysis of changes in researcher demographics and scholarly agendas. *PloS one*, *17*(1), e0262027.

[123] Koning, R., Samila, S., & Ferguson, J. P. (2021). Who do we invent for? Patents by women focus more on women's health, but few women get to invent. *Science*, *372*(6548), 1345-1348.

[124] Kozlowski, D., Larivière, V., Sugimoto, C. R., & Monroe-White, T. (2022). Intersectional inequalities in science. *Proceedings of the National Academy of Sciences*, *119*(2), e2113067119.

[125] Gendered Innovations, Gender Impact Assessment. http://genderedinnovations.stanford.edu/methods/impact.html

[126] European Institute for Gender Equality. (2017). *Gender Impact Assessment: Gender Mainstreaming Toolkit*. Luxembourg: Publications Office of the European Union. https://eige.europa.eu/publications/gender-impact-assessment-gender-mainstreaming-toolkit

4. Develop an index for social equity and environmental sustainability for industry. Many industries have developed inclusive workforces. Industry now needs to embrace evaluating their products, services, and infrastructures for social equity and environmental sustainability. Life cycle assessment and social life cycle assessment are tools that can be employed. The Gendered Innovations group is currently developing intersectional life cycle assessment tools.

5. Expand RRI and Equity, Diversity, and Inclusion (EDI) to include the type of research (topic) being done and how research is being done (methodology). RRI and EDI typically focus on participation. These need to expand to consider what S&T is produced.

6. UN monitoring and evaluation of gender equality should be expanded beyond participation issues to consider gender in knowledge (S&T) production.[127]

[127] United Nations Department for General Assembly and Conference Management, Gender Equality, https://www.un.org/dgacm/en/content/gender-equality