ABSTRACT
This article explores the aims, strategies, developments, successes, and challenges of Gendered Innovations from its inception in 2005 to today. Gendered Innovations employs methods of sex, gender, and intersectional analysis to overcome past bias and, importantly, to create new knowledge. It seeks to harness the creative power of sex, gender, and intersectional analysis for innovation and discovery. The operative question is: does considering these factors add valuable dimensions to research? Do they take research in new directions? Gendered Innovations: (1) develops practical methods of sex, gender, and intersectional analysis specifically for natural scientists and engineers; and (2) provides case studies as concrete illustrations of how sex, gender, and intersectional analysis leads to discovery. The article discusses where Gendered Innovations fits within the equality, diversity, and inclusion landscape. The article focuses on the international reach of the project, collaborative and interdisciplinary methods for developing materials, sample case studies, and policy initiatives that support excellence in science. Case studies previewed include machine translation, facial recognition, menstrual cups, and marine science; these examples work to support social equalities and also the United Nations Sustainable Development Goals.

KEYWORDS
Gendered Innovations; sex analysis; intersectionality; gender analysis; sustainable development goals

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Gendered Innovations: integrando al sexo, el género y el análisis interseccional en la ciencia, la salud y medicina, ingeniería y medio ambiente

En este artículo se exploran los objetivos, estrategias, desarrollos, éxitos y desafíos del programa Gendered Innovations (GI) desde su creación en 2005 hasta la actualidad. GI emplea métodos de análisis de sexo, género y el análisis interseccional para superar los prejuicios del pasado y, sobre todo, para crear nuevos conocimientos. Su objetivo es aprovechar el poder creativo del análisis de sexo, género y el análisis interseccional para la innovación y el descubrimiento. La pregunta clave es, ¿el análisis de género añade una dimensión valiosa a la investigación? Además, ¿lleva a la investigación en nuevas direcciones? GI: (1) desarrolla métodos prácticos de análisis de sexo y género específicamente para científicos naturales e ingenieros; y (2) proporciona estudios de caso como ilustraciones concretas de cómo el análisis de sexo, género e interseccional conduce a descubrimientos. El artículo analiza el lugar que ocupa GI en el ámbito de la igualdad, la diversidad y la inclusión. El artículo se centra en el alcance internacional de los proyectos, así como en los métodos de colaboración e interdisciplinariedad para el desarrollo de materiales didácticos, estudios de caso e iniciativas políticas que apoyan la excelencia en la ciencia. Los estudios de casos incluyen: la traducción computarizada, el reconocimiento facial, las copas menstruales y la ciencia marina. Estos ejemplos sirven para apoyar la igualdad social y adicionalmente los Objetivos de Desarrollo Sostenible de las Naciones Unidas.

“Gendered Innovations” was coined as a term and incubated at Stanford University in 2005. As the director of the Clayman Institute for Gender Research, I had the opportunity to push forward a research agenda on gender in the natural sciences and engineering. The immediate issue was a conference and volume on gender, science, and technology. Since the 1980s, major epistemologists in the field, such as Evelyn Fox Keller, Donna Haraway, Sandra Harding, among others, worked in conceptually sophisticated ways to reveal gender bias in science (Keller 1985; Haraway 1988; Harding 1991, see also...
Schiebinger (2014b). This is where my historical work also sought to make contributions (Schiebinger 1989, 1993).

Identifying gender bias and understanding how it operates is crucially important, but analysis cannot stop there. “Gendered Innovations” builds from critique toward a positive research program that employs gender analysis as a resource to stimulate new knowledge and innovation. New terminology has been an important part of the solution.

But there were other problems. That 2005 conference brought together leaders in the field, from the University of California, Berkeley’s Margaret W. Conkey to discuss fascinating work in archaeology documenting feminist upheavals that remade that field over the past thirty years to Sweden’s Tatiana Butovitsch Temm to present the new Volvo designed entirely by women. (Ironically, we were too late to book the car itself.) The chapters in the ensuing volume were long and beautifully complex – representative of the best work on gender in the social sciences and humanities (Schiebinger 2008). I could see, however, that this chapter-based format was not one that would allow gender analytics to travel to the natural sciences – and, in an extreme reach, to engineering.

From these and various other experiments, Gendered Innovations in its current form was born. It manifests in a living website with over 600,000 users from 169 countries around the world – and has been translated into German, Korean, Spanish, Swedish, and Taiwanese (traditional Chinese). Gendered Innovations has a strong presence across the European Union, the US, Canada, and the Republic of Korea. We are making forays into Japan, Brazil, Argentina, South Africa, among other geographic locations. In an effort to reach industry leaders, such as Google, Facebook, and the like, we rolled out a series of Tech Roundtables in Silicon Valley.

What is Gendered Innovations? Gendered Innovations employs methods of sex, gender, and intersectional analysis to create new knowledge. It seeks to harness the creative power of this type of analysis for innovation and discovery. The operative question is: Does considering these factors add valuable dimensions to research? Do they take research in new directions?

To answer these questions, Gendered Innovations (GI): (1) develops practical methods of sex, gender, and intersectional analysis for scientists and engineers; and (2) provides case studies as concrete illustrations of how this type of analysis leads to discovery and innovation. Our focus is on sex and gender, and we consider intersectional factors, such as race and ethnicity, socioeconomic status, age, abilities, geographic locations, sexual orientation, sustainability, etc., in relation to those categories in our case studies.

Sex, gender, and intersectional analysis is crucial to all stages of research from strategic considerations for establishing priorities and theory to more routine tasks of formulating questions, developing methodologies, and interpreting data (Figure 1). State-of-the-art methods of sex, gender, and intersectional analysis work alongside other methodologies in a field to provide yet further “controls,” or filters, for bias. As with any set of methods, new ones will be fashioned and others discarded as circumstances change. The value of their implementation depends on the creativity of the research team.

Landing on the case study format was a breakthrough moment. I was inspired by the US National Science Foundation (NSF) ADVANCE program that provided numerous

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1http://genderedinnovations.stanford.edu/. Retrieved June 15, 2020.
2https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383. Retrieved July 27, 2020.
carefully documented examples of unconscious gender bias in research institutions. These were examples that could be exchanged in three sentences: They were strategic “elevator speeches.” I knew we needed similarly short, attention-grabbing examples of how sex, gender, and intersectional analysis leads to discovery. To see what worked best with various audiences, I convened focus groups and tested our materials across various disciplines – from biologists to engineers to physical scientists. I learned a great deal about how scientists and engineers read differently from humanists. We continued to tweak our format until it worked for them.

To ensure quality, everything on the Gendered Innovations website is peer reviewed. To date, GI has brought together over 170 researchers with gender experts in a series of collaborative workshops. For each case study, I constitute a panel of experts for that specific topic. For example, in 2018, we held a workshop on machine learning at Stanford. Working with my collaborator, James Zou, we invited computer scientists from across Stanford, Google, and Facebook along with gender experts with interest in the field. The results were published on the website and in *Nature* (Zou and Schiebinger 2018).

Where does GI fit in the equality, diversity, and inclusion landscape? Over the past several decades, governments, universities, and, increasingly, companies in the US and Western Europe have taken three strategic approaches to gender equality:

(1) “Fix the Numbers” focuses on increasing the numbers of women and underrepresented groups participating in science and technology. Efforts in this area began in earnest in the 1980s. Government agencies both gathered statistics on participation in the scientific and engineering workforce and provided programs to jump-start

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3http://genderedinnovations.stanford.edu/people.html. Retrieved July 27, 2020.
4http://genderedinnovations.stanford.edu/case-studies/machinelearning.html#tabs-2.
newcomers’ careers – by increasing funding for research, teaching negotiation skills, setting up mentor networks, and the like. Support for careers is vital, but, by itself, does not create equality: research institutions need to be transformed.

(2) “Fix the Institutions” promotes equality in careers through structural change in research organizations. Since the 2000s, governments and universities have worked to reduce conscious and unconscious bias in hiring and promotion, and to render institutions more diversity-friendly. Transforming institutions is crucially important, but these reforms can take place while assuming that what goes on inside those institutions – research and knowledge production – is value neutral. Restructuring institutions must be joined to efforts to eliminate bias in knowledge.

(3) “Fix the Knowledge” or “gendered innovations” stimulates excellence, reproducibility, and responsibility in science and technology by integrating sex, gender, and intersectional analysis into research.

While it is useful to distinguish these strategic approaches for analytical purposes, they are interlocking parts of a larger whole. While people often assume diversity in research teams leads to innovation, it is important to understand that recruiting and retaining women or underrepresented groups in science and engineering will not succeed until the deeper issues in the organization of institutions and production of knowledge are understood and transformed (Nielsen et al. 2018).

Let me be perfectly clear. The goal of equality for women, men, and gender- and ethnically diverse individuals as scientists and engineers is important, and supports the United Nations (UN) Sustainable Development Goal (SDG), # 5 – *Gender Equality*. But there is a larger goal: Excellence in science and engineering research, policy, and practice. To achieve this larger goal, it is not enough to bring women and underrepresented groups into science. All scientists and engineers need to learn basic analytical skills that lead to excellence in research. One set of skills still lacking in much graduate and profession training is sex, gender, and intersectional analysis. These are skills that all practitioners need to learn – and not something we should expect more of newcomers, such as women, than others. In fact, newcomers may not be any better trained in this type of exacting analysis than other scientists and engineers. Designing sex, gender, and intersectional analysis into research is one crucial component contributing to world-class science and technology (Tannenbaum et al. 2019). To reap the benefits of this type of analysis worldwide will require coordinating policy across three domains of science infrastructure: funding agencies, peer-reviewed journals, and universities – more on that later.

1. Gendered Innovations 1

Gendered Innovations officially launched in 2009 at Stanford University; the website was designed, tested, up and running by 2010. The great leap forward came in 2011 when representatives from the European Commission (EC) arrived in my office to propose funding a group of experts from across Europe and North America to advance Gendered Innovations. The EC sought intellectual foundations and resources for its planned Horizon 2020 funding framework (2014–2020) that would strengthen what Europeans call the “gender dimension in research content.” Since 2003, the EC has been a global leader in policy to support integrating sex and gender analysis into research. These policies were
to be reaffirmed and expanded in Horizon 2020. The Commission states, “Integrating gender/sex analysis in research and innovation (R&I) content … helps improve the scientific quality and societal relevance of … technology and/or innovation.” A group of us honed the one-sentence guideline prompt for all applicants seeking public funding over dinner one evening for nearly two hours: “Where relevant, describe how sex and/or gender analysis is taken into account in the project’s content.” The prompt had to be sufficiently general that it could apply to all areas of research, and, importantly, had to include “where relevant,” since it might not apply to certain areas, such as theoretical physics or pure mathematics.

Stanford University supported GI since its inception. The US NFS joined the project January 2012. To match the global reach of science and technology, GI held seven international, peer-reviewed, interdisciplinary, and, to the extent possible, gender-balanced workshops convened – by Marcia Stefanick and myself at Stanford, February 2011; by co-director Martina Schraudner in Berlin, March 2011; by co-director Ineke Klinge in Maastricht, June 2011; by Caroline Bélan-Ménagier in Paris, March 2012; by co-director Inés Sánchez de Madariaga in Madrid, May 2012; by Sarah Richardson at Harvard, July 2012; and by the EC in Brussels, September 2012. At these workshops of about 18 researchers each, we reviewed and completed methods and case studies. The case studies were exciting and took gender research into new areas.

Already in 2012, we crafted a case study on Machine Translation, which included insights on how to integrate gender analysis into natural language processing. This predated the 2016 breakthrough article, “Man is to Computer Programmer as Woman is to Homemaker? Debiasing Word Embeddings” (Bolukbasi et al. 2016). The insight came when one of my Stanford students, Tina Roh, was taking a course on natural language processing from Dan Jurafsky and a course on gendered innovations from me at the same time. She had the insight that gender analysis could profitably be applied to natural language processing.

Soon thereafter, I experienced the type of bias she had uncovered. I was lecturing in Madrid and interviewed by some Spanish newspapers. When I returned home, I put the articles through Google translate and was shocked that I was referred to repeatedly as “he.” Londa Schiebinger, “he said,” “he wrote,” and, occasionally, “it thought.” Google Translate has a male default.

This problem is larger than simply misidentifying my gender. When a translation program defaults to “he said,” it reinforces the stereotype that men are active intellectuals by changing a “she” in this role to a “he” – “they” did not appear as an option. This gender switch increases the relative frequency of the masculine pronoun in the database thus amplifying unconscious gender bias from the past into the future. Importantly, Google translate is creating the future; we are well aware that our devices, programs, and processes shape human attitudes, behaviors, and culture. In this case, past bias is perpetuated into the future, even when governments, universities, and Google itself have implemented policies to foster equality. The big question is: How can humans intervene in automated processes to create the society we want?

5http://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-major-granting-agencies.html Retrieved July 27, 2020.
6For a full list of funders, see: http://genderedinnovations.stanford.edu/people.html. Retrieved July 27, 2020.
The floodgates of working to remove bias from machine learning were opened. We convened a workshop with a representative from Google Translate, my colleague Dan Jurafsky, and gender experts. Google was shocked and after about twenty minutes exclaimed, “we can fix that!” Fixing it is great, but constantly retrofitting for women or non-binary people is not the best road forward. What if Apple, Google, and other companies started product development research by incorporating gender analysis? What innovative new technologies could be conceived?

Google has released several fixes over the past several years. They claim that Translate can now achieve “gender-specific translations with an average precision of 97%.”7 A quick recheck of the original Spanish article revealed, however, that the translation is still replete with “he,” although the algorithm now more often retrieves “she.” It can be harder to fix something once the basic platform is set – which is why it is important to analyze gender from the very beginning.

Other new and exciting case studies included Assistive Technology for the Elderly, which emphasized how sex and gender interact.8 HIV Microbicide provided a high-tech solution to HIV prevention but cautioned that gender norms intersect with differing sexual practices across geographic locations. De-Gendering the Knee warned against over-emphasizing sex differences to the exclusion of other factors, such as height.9 Osteoporosis Research in Men found interesting intersections between sex, gender, and race.10 Nutrigenomics analyzed intersections between gender, body mass index (BMI), and geographic locations.11 Water Infrastructure explored how participatory research could tap into women’s local knowledge developed from basic divisions of labor that played out in the burdensome task of water collection in sub-Saharan Africa.12

The project occasionally encountered bumps. We convened a workshop on sex and gender in neuroscience. By the end of two days, experts were dug into two warring camps; there was not even eye contact across battle lines. We also convened a workshop on animal research, where I very much wanted to explore how sex and gender interact in animal labs. The basic science researchers, however, did not want any talk of gender in relation to animals. Those discussions were fascinating. We published a comment in the Proceedings of the National Academy of Sciences (Klein et al. 2015) and finally agreed on a case study, Animal Research 2, which emphasizes how environmental factors in the lab that might impact male and female animals differently should not be misinterpreted as biological sex differences.13 In preparation for National Institute of Health’s 2016 requirement that all researchers must consider “sex as a biological variable,” we worried that artifacts of lab practices, such as caging, room temperature, diet, or researcher sex, etc., might be misinterpreted as biological sex differences.

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7 https://slator.com/machine-translation/google-fxes-gender-bias-in-google-translate-again/#:~:text=But%20Google%20Translate%20now%20right%2097%25%20of%20the%20time. Retrieved June 11, 2020.
8 http://genderedinnovations.stanford.edu/case-studies/robots.html#tabs-2. Retrieved December 4, 2020.
9 http://genderedinnovations.stanford.edu/case-studies/knee.html#tabs-2. Retrieved December 4, 2020.
10 http://genderedinnovations.stanford.edu/case-studies/osteoporosis.html#tabs-2. Retrieved December 4, 2020.
11 http://genderedinnovations.stanford.edu/case-studies/nutri.html#tabs-2. Retrieved December 4, 2020.
12 http://genderedinnovations.stanford.edu/case-studies/water.html. Retrieved December 4, 2020.
13 http://genderedinnovations.stanford.edu/case-studies/animals2.html#tabs-2. Retrieved December 4, 2020.
All Gendered Innovations materials were presented at the European Parliament July 2013. These materials are available to researchers applying for grants at the EC or elsewhere in the world. We built the website to be nimble; my goal was that it should work for someone in rural India, London, or Sydney as it does in San Francisco.

In 2014, I returned to my historical work to write the *Secret Cures of Slaves: People, Plants, and Medicine in the Eighteenth-Century Atlantic World*. People often ask how, as a historian, I direct Gendered Innovations. The answer is simple: History is a set of analytical tools that can be turned to any topic. All of my work since *The Mind Has No Sex?* has analyzed sex, gender, race, and their intersections in specific social contexts. Gendered Innovations is no different: We formalized the plethora of methods surrounding sex, gender, and intersectional analysis initially into twelve methods, and apply them in our case studies. History often analyzes science after the fact; the goal of Gendered Innovations is to get the research right from the very beginning. By preemptively employing methods of sex, gender, and intersectional analysis, scientists and engineers can better ensure excellence in outcomes and make science more responsive to social needs.

And Gendered Innovations traveled. I and colleagues presented rationale and case studies in lectures and interactive workshops all across Europe and North America primarily to scientists and engineers. In Sweden, one young man excused himself from the workshop saying he just "got it" and needed to revise a grant he was about to submit on heart disease to include sex differences between women and men. In 2013, doors opened in Asia. It began with a keynote in Taiwan to the International Conference on Women in Science and Technology. These workshops work best by illustrating methodological points with stories. Take, for example, the important point: *Sex interacts with sex*. Here I tell the story of the nematode, *C. elegans*, where the presence of males accelerates aging of individuals of the opposite sex (in this case, hermaphrodites). In animal research, males and females are often studied separately. Yet in the wild, the sexes coexist – and this may influence their longevity. What kills the unsuspecting hermaphrodites? Pheromones released by males. Male-induced demise can occur without mating and requires only that the hermaphrodites are exposed to the medium in which males were once present (Maures et al. 2014).

Or when I want to make the point that the *sex of the experimenter* may impact the experiment, I present the great pain research by Jeffrey Mogil at McGill University, Canada, that shows that rats and mice in the lab do not show pain when a male researcher is present, but will show their pain when a female is in the room or to an empty room (Sorge et al. 2014).

What’s going on? The animals smell the male; they smell male pheromones. This “male-observer effect” often elicits a laugh or exclamation. It is extremely vivid – and an example that can be repeated in lab, to friends over coffee, or in the classroom. And it’s significant: This phenomenon may throw into question all prior results from pain research.

The greatest impact of GI in Asia has been in the Republic of Korea. There, Hee Young Paik, a co-director of GI, procured governmental funds to found a Center for Gendered

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14Schiebinger and Klinge (2013), with a foreword by EC Commissioner for Research, Innovation, and Science, Máire Geoghegan-Quinn. Available at: https://web.stanford.edu/dept/HPST/2012.4808_Gendered%20Innovations_web2.pdf. Retrieved December 4, 2020.
15Published by Stanford University Press in 2017.
16For more on this topic, see Schiebinger (2014a), Interview (2015), Gibney (2020).
Innovations in Science and Technology Research in Seoul in 2016.\textsuperscript{17} Starting with basic science, health, and medicine, this group prepared two case studies for GI: Colorectal Cancer, where women have a higher risk than men of developing aggressive, proximal cancers,\textsuperscript{18} and Dietary Assessment Methods, where the types and amounts of foods people consume differ by sex and gender.\textsuperscript{19} While many national science funding agencies have policies on integrating sex and gender into research for successful grant applications, in Korea this is regulated by national law – and difficult to implement. Toward that end, I spoke at the Korean National Assembly in 2014 to support gendered innovations in medicine, the field with the greatest evidence of efficacy; to my knowledge, no policy changes have been implemented.

Japan, too, has been actively holding meetings to discuss sex and gender analysis at the Japan Science and Technology Agency and the Science Council of Japan. A special session on gendered innovations was held at the US Embassy in Tokyo in 2018. NHK, national Japanese television, aired an eight-minute segment on gendered innovations in 2018.

To my regret, Gendered Innovations has no presence in mainland China.

Gendered Innovations has made forays into Latin America. In 2019, I addressed the Global Research Council – an annual meeting of the heads of science and engineering funding agencies from around the world – in São Paulo, Brazil, where I was introduced by France A. Córdova, then director of the US NSF, and Andrew Thompson from UK Research and Innovation. In the audience were representatives from the Ivory Coast, France, New Zealand, etc. I also spoke at the National Autonomous University of Mexico in Mexico City and (virtually) at a conference on Gender and Science, Technology, and Innovation in Santa Fe, Argentina. Much needs to be done in Latin America, but networks are developing and growing.

2. Gendered Innovations 2

In late 2018, Gendered Innovations received funding from the European Commission to develop what we call Gendered Innovations 2. This group consisted of 29 experts – from systems biology to machine learning to civil engineering, among other fields. We met in three in-person workshops in Brussels and developed some fifteen new case studies, ranging from analyzing sex in marine science – something completely new – to analyzing gender in smart energy solutions and quality urban spaces. The new project was ready to go March 2020, but the launch was delayed until November by the dangers and devastation of the coronavirus.\textsuperscript{20}

Here I highlight several of our new case studies beginning with our case study on facial recognition. Like other technologies reliant on big data, facial recognition systems can perpetuate, and even amplify, social injustices by consciously or unconsciously encoding human bias. A now well-known study, Gender Shades by Joy Boulamwini and Timnit Gebru, measured the accuracy of commercial facial recognition systems – including

\begin{footnotesize}
\footnotetext{17}{http://gister.re.kr/#l/main. Retrieved June 4, 2020.}
\footnotetext{18}{http://genderedinnovations.stanford.edu/case-studies/colon.html. Retrieved July 27, 2020.}
\footnotetext{19}{http://genderedinnovations.stanford.edu/case-studies/dietary.html. Retrieved July 27, 2020.}
\footnotetext{20}{Schiebinger and Klinge (2020), with a foreword by EC Commissioner for Innovation, Research, Culture, Education, and Youth, Mariya Gabriel.}
\end{footnotesize}
those from Microsoft, IBM, and Face++ – and found that these systems performed better on men’s faces than on women’s faces (sex analysis), and that all systems performed better on lighter-skin than darker-skin (race analysis). When they considered how sex and race intersect, they saw that error rates were 35% for darker-skinned women, 12% for darker-skinned men, 7% for lighter-skinned women, and less than 1% for lighter-skinned men (Buolamwini and Gebru 2018). The fix? The team developed and labeled a new intersectional dataset to test sex and race classification performance on four subgroups: darker-skinned women, darker-skinned men, lighter-skinned women, and lighter-skinned men. Their dataset consisted of 1270 images from three African countries (Rwanda, Senegal, and South Africa) and three European countries (Iceland, Finland, and Sweden). Using this or similar new datasets, all commercial systems improved accuracy (Raji and Buolamwini 2019).

Facial recognition also encounters striking problems related to gender. Wearing facial makeup can reduce the accuracy of facial recognition up to 76.21% (Dantcheva et al. 2012) – a real concern if facial recognition is used for airport security, for example. One proposal to overcome these issues is to map and correlate multiple images of the same person with and without makeup. For these systems to work, coders will also need to take into account different makeup practices across cultures. A second, and more troublesome gender issue, has to do with transgender individuals. Transgender faces may pose challenges for facial recognition systems (Keyes 2018). Gender-affirming hormone therapy can change the overall shape and texture of the face. In this case, it may be important to revise algorithmic parameters to rely on the eye (or periocular) region.21

One goal is to perfect this technology to make it work for everyone. The use of facial recognition, however, may endanger vulnerable communities, and many are taking steps to rein in its use. The potential misuse of facial recognition has led to several actions: Belgium has declared the use of facial recognition illegal, France and Sweden have expressly prohibited it in schools, and San Francisco has banned its use by local agencies, such as the transport authority or law enforcement.22 Companies, too, are pulling back: IBM has left the business entirely, and Amazon has halted police from using its technology for one year in response to worldwide protests against systemic racial injustices in 2020. Seeking long-term solutions, the US Algorithmic Justice League has called for the creation of a federal office similar to the US Food and Drug Administration to regulate facial recognition (Learned-Miller et al. 2020).

An important new case study looks at menstrual cups and intersections between menstrual products and environmental sustainability. Menstrual products, such as tampons and pads, cost US consumers some $3.1 billion per year. At the same time, 49.8 billion tampons and pads plus their packaging clog landfills or sewer systems each year in the US. This case study explores how menstrual cups are: (1) good for the environment – supporting the UN SDG #6 Clean Water and Sanitation; (2) good for gender equality – supporting the UN SDG #5 Gender Equality; (3) good for health – supporting the UN SDG #3 Good Health & Well-Being; and (4) good for helping to sustain school attendance in developing

21http://genderedinnovations.stanford.edu/case-studies/facial.html. Retrieved July 27, 2020.
22Surfshark. Retrieved June 15, 2020, from https://surfshark.com/facial-recognition-map. Retrieved July 27, 2020.
countries, by providing safe and reliable menstrual hygiene – supporting the UN SDG #1 *No Poverty*. Gendered Innovations is extending this work with an environmental life-cycle assessment of pads, tampons (of various types), reusable pads, period panties, and menstrual cups (still in progress). Menstruation is a fact of life but still all too often a taboo subject. To break the ice, when I teach this topic in class, I have students (about 40 percent of whom are men) shout “menstruation” very loudly three times. Our goal in this work is to support menstruators to find individually comfortable, socially equitable, and environmentally sustainable ways to manage menstruation.

We have many new case studies that I could review here. The final one I want to mention explores marine science. This case study urges marine scientists to analyze sex – a simple message with potentially huge consequences. Analyzing biological sex in marine science is crucial to support the UN SDG #14, *Life below Water*.

As this case study shows, the sex ratio of a population is a main determinant of its resilience to climate change. Yet, sex analysis is largely overlooked by marine scientists. A recent systematic review of ocean acidification literature, for example, revealed that only 3.7% of studies tested for sex differences (Ellis et al. 2017). Failing to account for such differences impacts our ability to effectively manage ecosystems and set conservation priorities.

Temperature-dependent sex determination in marine turtles is perhaps the most widely studied and well-known mechanism of environmental sex determination. These species are especially vulnerable to climate change. Recent studies of northern green sea turtles on Australia’s Great Barrier Reef have shown that populations on northern reefs (which are warmer) have been feminized. Over 99% of juveniles and sub-adults originating from these sites are female (compared to 67% female at southern sites–Jensen et al. 2018). Populations that approach 99% female are in danger of collapse and extinction.

This work also challenges simplistic notions of sex by revealing that marine organisms come in many sexual flavors. Some are protandrous hermaphrodites, maturing as male then changing sex to female; others are protogynous, maturing as female and then changing sex to male. In still others, sex can be influenced by social organization. Clownfish, for example, are protandrous hermaphrodites that live in a strict social hierarchy with a single dominant and highly fecund female at the top who mates with a single large male in the social group; all remaining individuals remain immature juveniles. Removal of the alpha female results in the alpha male changing sex to female, with all subordinates moving up a rung in the social hierarchy (Tannenbaum et al. 2019).

The success of Gendered Innovations has depended on the talents of many people. Ineke Klinge, professor of public health in the Netherlands, and Marcia Stefanick, professor of preventive medicine at Stanford, have been my partners in Gendered Innovations from the beginning. Addison Arlow, a Stanford graduate in chemistry and aspiring science writer, served as a talented research assistant for two crucial years. Rosemary Rogers has served as a creative webmistress. Viviane Willis-Mazzichi was the EC program officer for GI 1 and Anne Pépin for GI 2 – they served as conduits between GI and the EC, effectively managing to keep all the balls in the air. GI is now cultivating a new generation of leaders and expanding participation globally.

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23http://genderedinnovations.stanford.edu/case-studies/menstrualcups.html#tabs-2. Retrieved July 27, 2020.
24http://genderedinnovations.stanford.edu/case-studies/marine.html. Retrieved July 27, 2020.
25http://genderedinnovations.stanford.edu/methods/herma.html. Retrieved December 4, 2020.
3. The road forward: science infrastructure

Policy is one driver of innovation that can encourage scientists and engineers to integrate sex and gender analysis into their research. Interlocking policies need to be implemented across the three pillars of academic research: funding agencies, peer-reviewed journals, and universities (Figure 2).

Public funding agencies can lead the way by asking applicants to explain how sex, gender, and intersectional analysis is relevant to their proposed research, or to explain that it is not. Since 2012, Gendered Innovations created and maintains a page listing sex and gender policies of major granting agencies – along with links to those policies (see note 5). Global leaders in this respect are the Canadian Institutes of Health that have had policies encouraging applicants to report how sex and/or gender is analyzed in the research protocol, or to justify their exclusion, since 2010. The European Commission has had such policies across all the sciences since 2014; and in its new funding framework, Horizon Europe, is seeking to require sex and gender analysis in all research and innovation, where relevant.26 In 2016, the US National Institute of Health put in place a requirement that all public-funded grants include “sex as a biological variable.”27 NIH does not yet require gender analysis.

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26At this writing, the policy had not yet been officially passed.
27For NIH policy, see Arnegard et al. (2020). See also CIHR’s online training modules for integrating sex and gender in biomedical research and NIH’s online training modules. Retrieved December 4, 2020.
Gendered Innovations is currently working with Equality, Diversity & Inclusion in Science and Health at the Wellcome Trust to evaluate granting agencies according to the quality of these policies (we are developing evaluation criteria now). In this way, we hope to better understand what is going on worldwide with respect to agencies supporting excellence in science by requiring sex, gender, and intersectional analysis, where relevant. Our aim is to provide publicly funded agencies with a global map of best practices in this area.

The second pillar of academic research, peer-reviewed journals, can require sophisticated sex and gender analysis, where relevant, when selecting papers for publication. Since 2012, Gendered Innovations created and maintains a list of journals with such policies – along with links to those policies.\textsuperscript{28} Importantly, in 2016, the European Association of Science Editors published their now widely adopted Sex and Gender Equity in Reporting (SAGER) guidelines that outline procedures for reporting sex and gender in study design, data analyses, results, and interpretation of findings (Heidari et al. \textit{2016}). While health and medical journals have moved rapidly to adopt such guidelines, engineering or computer science conferences and journals have not. There is, however, a movement among large artificial intelligence/machine learning conferences to review papers for ethics before accepting them. In 2020, Neural Information Processing Systems (NeurIPS) led the way, stating that a “submission may be rejected for ethical considerations, including methods, applications, or data that create or reinforce unfair bias or that have a primary purpose of harm or injury.”\textsuperscript{29} These ethical considerations encompass issues related to gender and ethnicity.

Finally, we come to the third pillar: universities.\textsuperscript{30} To prepare the workforce for the future, universities need to incorporate sex, gender, and intersectional analysis as conceptual tools in technical courses in the natural science, medicine, and engineering. Numerous universities offer gender analysis in the humanities and social sciences, but they rarely teach gender analysis where science and engineering students live, i.e. in their core technical courses.

Interestingly, Harvard University has pioneered an Embedded EthiCS course – in response to student demand – that integrates ethical issues into the computer science curriculum. Barbara Grosz et al. argue that embedding ethical reasoning throughout the entire CS curriculum has the potential to habituate students to thinking ethically as they develop algorithms and build systems, both in their studies and as they pursue technical work in their careers.\textsuperscript{31} These interdisciplinary courses are taught by humanists and computer scientists. Integrating ethics into technical courses is preferable to stand-alone ethics courses, which are typically electives, and students can graduate without ever having taken one. Harvard’s approach can be expanded from computer science more broadly across engineering and the basic sciences.

The medical sciences are doing somewhat better. The Charité in Berlin, Germany, is one of the few medical schools that has successfully integrated sex and gender analysis across its medical curriculum (Ludwig et al. \textit{2015}). But across the US and around the world we

\begin{footnotesize}
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\item \textsuperscript{28}http://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-peer-reviewed-journals.html. Retrieved July 27, 2020.
\item \textsuperscript{29}https://nips.cc/Conferences/2020/CallForPapers. Retrieved July 27, 2020.
\item \textsuperscript{30}http://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-curriculum.html. Retrieved July 27, 2020.
\item \textsuperscript{31}Watch the 4 min video; see the course modules; read the article: Grosz et al. Waldo. (2019).
\end{itemize}
\end{footnotesize}
have had little success, despite the Sex and Gender Health Education Summits that have been held since 2015.\textsuperscript{32}

We should not forget industry and the role it has to play in fostering more equal and just societies. In 2016, Gendered Innovations launched a “Design Thinking” portal aimed specifically at companies.\textsuperscript{33} At that time, we also developed the first gender course for Stanford’s d.school (Design School). The goal of this work is to encourage startups as well as established companies to incorporate gender analysis in the earliest stages of product development – even when setting priorities for what products, services, and infrastructures to develop.

Much work remains to be done. But working together, we can accomplish a lot. Educators are welcome to use GI materials in their courses. Researchers can alert colleagues to the urgent need to incorporate sex, gender, and intersectional analysis in the natural sciences, engineering, and medicine. Editors of peer-reviewed journals, especially those in science and technology, can put in place editorial policies that add sex, gender, and intersectional analysis to criteria for publication. Granting agency directors, staff, and proposal reviewers can insist that policies be developed that require public-funded research to integrate sex, gender, and intersectional analyses. Gendered innovations adds value to research by enhancing excellence, offering new perspectives, posing new questions, and helping to ensure that research findings are applicable across the whole of society.

When I was in graduate school at Harvard University in the early 1980s, I was told that working on anything related to gender was professional suicide. But it was too late. I had already discovered the burgeoning feminist literature in the field of history and attended what was billed as the first Women Scientists’ Workshop at the Massachusetts Institute of Technology. Literature on gender and science was just about to pour forth with Sandra Harding’s important book, \textit{The Science Question in Feminism}, appearing in 1986. From these humble beginnings, who could have imagined that gender analysis would become part of the criteria for public funding in science and technology? Who could have imagined that sex, gender, and intersectional analysis had so very much to contribute to discovery and innovation? It has been humbling to have made a small contribution to this large, global endeavor.

\textbf{Disclosure statement}

No potential conflict of interest was reported by the author(s).

\textbf{Notes on contributor}

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\textsuperscript{32}https://www.sghesummit2018.com/. Retrieved July 27, 2020.

\textsuperscript{33}http://genderindesign.com/. Retrieved December 4, 2020.
Innovations 2: How Inclusive Analysis Contributes to Research and Innovation (2020); “Sex and Gender Analysis Improves Science and Engineering,” Nature (2019); “AI Can Be Sexist and Racist – It’s Time to Make it Fair,” Nature (2018); The Secret Cures of Slaves (2017); Plants and Empire (2004); Has Feminism Changed Science? (1999); Nature’s Body (1993); The Mind Has No Sex? (1989).

References

Arnegard, Matthew E., Lori A. Whitten, Chyren Hunter, and Janine Austine Clayton. 2020. “Sex as a Biological Variable: A 5-Year Progress Report and Call to Action.” Journal of Women’s Health 29 (6): 858–864.

Bolukbasi, Tolga, Kai-Wei Chang, James Zou, Venkatesh Saligrama, and Adam Kalai. 2016. “Man is to Computer Programmer as Woman is to Homemaker? Debiasing Word Embeddings.” Advances in Neural Information Processing Systems 29: 4349–4357.

Buolamwini, Joy, and Timnit Gebru. 2018. “Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification.” Proceedings of Machine Learning Research 81: 77–91. Accessed July 27, 2020. http://gendershades.org

Dantcheva, Antitza, Cunjian Chen, and Arun Ross. 2012. “Can Facial Cosmetics Affect the Matching Accuracy of Face Recognition Systems?” IEEE Fifth International Conference on Biometrics: Theory, Applications and Systems: 391–398.

Ellis, Robert P., William Davison, Ana M. Queirós, Kristy J. Kroeker, Piero Calosi, Sam Dupont, John I. Spicer, Rod W. Wilson, Steve Widdicombe, and Mauricio A. Urbina. 2017. “Does Sex Really Matter? Explaining Intraspecies Variation in Ocean Acidification Responses.” Biology Letters 13 (2): 20160761. doi:10.1098/rsbl.2016.0761.

Gibney, Elizabeth. 2020. “The Researcher Fighting to Embed Analysis of Sex and Gender into Science.” Nature. Accessed December 4, 2020. https://www.nature.com/articles/d41586-020-03336-8

Grosz, Barbara J., David Gray Grant, Kate Vredenburgh, Jeff Behrends, Lily Hu, Alison Simmons, and Jim Waldo. 2019. “Embedded EthiCS: Integrating Ethics Across CS Education.” Communications of the ACM 62 (8): 54–61.

Haraway, Donna. 1988. “Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspectives.” Feminist Studies 14: 575–599.

Harding, Sandra. 1991. Whose Science? Whose Knowledge? Thinking from Women’s Lives. Ithaca, NY: Cornell University Press.

Heidari, Shirin, Thomas F. Babor, Paola De Castro, Sera Tort, and Mirjam Curno. 2016. “Sex and Gender Equity in Research: Rationale for the SAGER Guidelines and Recommended Use.” Research Integrity and Peer Review 1: 1–9.

Interview. 2015. “Harnessing the Creative Power of Sex and Gender Analysis for Discovery and Innovation: Londa Schiebinger Meets Elisabeth Zemp Stutz and Elke Gramespacher.” Freiburger Zeitschrift für Geschlechterstudien, Medizin – Gesundheit – Geschlecht 21 (2): 115–126.

Jensen, Michael P., Camryn D. Allen, Tomoharu Eguchi, Ian P. Bell, Erin L. LaCasella, William A. Hilton, Christine A.M. Hof, and Peter H. Dutton. 2018. “Environmental Warming and Feminization of One of the Largest Sea Turtle Populations in the World.” Current Biology 28 (1): 154–159.

Keller, Evelyn Fox. 1985. Reflections on Gender and Science. New Haven, CT: Yale University Press.

Keyes, Os. 2018. The Misgendering Machines: Trans/HCI Implications of Automatic Gender Recognition.” Proceedings of the ACM on Human-Computer Interaction 2(CSCW): 1–22.

Klein, Sabra, Londa Schiebinger, Marcia Stefanick, Larry Cahil, Jayne Danska, Geert De Vries, Melinda Kibbe, et al. 2015. “Sex Inclusion in Basic Research Drives Discovery.” Proceedings of the National Academy of Science 112 (17): 5257–5258.

Learned-Miller, Erik, Vincent Ordóñez, Jamie Morgenstern, and Joy Buolamwini. 2020. “Facial Recognition Technologies in the Wild.” Accessed June 11, 2020. https://global-uploads.webflow.com/5e0e27ca188c99e3515b404b7/5ed1145952bc185203f3d009_FRTsFederalOfficeMay2020.pdf
Ludwig, Sabine, Sabine Oertelt-Prigione, Christine Kurmeyer, Manfred Gross, Annette Grüters-Kieslich, Vera Regitz-Zagrosek, and Harm Peters. 2015. “A Successful Strategy to Integrate Sex and Gender Medicine into a Newly Developed Medical Curriculum.” *Journal of Women’s Health* 24 (12): 996–1005.

Maures, Travis J., Lauren N. Booth, Bérénice A. Benayoun, Yevgeniy Izyayelit, Frank C. Schroeder, and Anne Brunet. 2014. “Males Shorten the Life Span of *C. elegans* Hermaphrodites via Secreted Compounds.” *Science* 343 (6170): 541–544.

Nielsen, Mathias W., Carter W. Bloch, and Londa Schiebinger. 2018. “Making Gender Diversity Work for Scientific Discovery and Innovation.” *Nature Human Behaviour* 2: 726–734.

Raji, Inioluwa D., and Joy Buolamwini. 2019. “Actionable Auditing: Investigating the Impact of Publicly Naming Biased Performance Results of Commercial AI Products.” In *Proceedings of the AAAI/ACM Conference on Artificial Intelligence, Ethics, and Society*. https://www.media.mit.edu/publications/actionable-auditing-investigating-the-impact-of-publicly-naming-biased-performance-results-of-commercial-ai-products/

Schiebinger, Londa. 1989. *The Mind Has No Sex? Women in the Origins of Modern Science*. Cambridge, MA: Harvard University Press.

Schiebinger, Londa. 1993. *Nature’s Body: Gender in the Making of Modern Science*. Boston, MA: Beacon Press.

Schiebinger, Londa, ed. 2008. *Gendered Innovations in Science and Engineering*. Stanford, CA: Stanford University Press.

Schiebinger, Londa. 2014a. “Following the Story: From the *Mind Has No Sex? To Gendered Innovations*.” In *Writing about Lives in Science: (Auto)Biography, Gender, and Genre*, edited by Paola Govoni and Zelda Alice Franceschi, 43–54. Göttingen: V&R Unipress.

Schiebinger, Londa, ed. 2014b. *Women and Gender in Science and Technology*, 4 vols. London: Routledge.

Schiebinger, Londa, and Ineke Klinge. 2013. *Gendered Innovations: How Gender Analysis Contributes to Research*. Luxembourg: Publications Office of the European Union.

Schiebinger, Londa, and Ineke Klinge, eds. 2020. *Gendered Innovations 2: How Inclusive Analysis Contributes to Research and Innovation*. Luxembourg: Publications Office of the European Union.

Sorge, Robert E., Loren J. Martin, Kelsey A. Isbester, Susana G. Sotocinal, Sarah Rosen, Alexander H. Tuttle, Jeffrey S. Wieskopf, et al. 2014. “Olfactory Exposure to Males, Including Men, Causes Stress and Related Analgesia in Rodents.” *Nature Methods* 11: 629–632.

Tannenbaum, Cara, Robert P. Ellis, Friederike Eyssel, James Zou, and Londa Schiebinger. 2019. “Sex and Gender Analysis Improves Science and Engineering.” *Nature* 575: 137–146.

Zou, James, and Londa Schiebinger. 2018. “AI Can Be Sexist and Racist – It’s Time to Make it Fair.” *Nature* 559 (7714): 324–326.