

BREAKING BARRIERS: FEMALE INVENTORS BLAZING A PATH FORWARD

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The gender gaps faced by women in our societies globally—in pay, education, and even health outcomes—are well known. Yet, we still seek commitment and workable policies to ensure that these gaps close. In the case of invention, a sizeable gap exists, as women patent significantly less than men, and this disparity is explored to some extent in this article. However, our main goal is to highlight women in the American Association for the Advancement of Science (AAAS)-Lemelson Invention Ambassadors program who have broken the barriers and become important inventors. By focusing on their achievements, we hope to inspire others around the world to ensure that more women have the opportunities necessary to increase their participation in solving global problems.

Key words: Women; Inventors; Innovators; Gender gap; Patent; Entrepreneurs

INTRODUCTION

The gender gaps faced by women in our societies globally—in pay, education, and even health outcomes—are well known. Yet, we still seek commitment and workable policies to ensure that these gaps close. In the case of invention, a sizeable gap exists, as women patent significantly less than men, and this disparity is explored to some extent in this article. However, our main goal is to highlight women in the American Association for the Advancement of Science (AAAS)-Lemelson Invention Ambassadors program who have broken the barriers and become important inventors. By focusing on their achievements, we hope to inspire others around the world

to ensure that more women have the opportunities necessary to increase their participation in solving global problems.

THE STATISTICS ARE DAUNTING

Successful female inventors are an integral part of the fabric of invention in the U.S. and other countries. Yet, both public knowledge of these women and the numbers of these women compared to men is significantly less than needed for the vibrant invention ecosystem required to solve global problems and create innovative technologies. In this article, we highlight a handful of the incredible women who have overcome barriers to become important inventors,

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particularly showcasing women inventors who are AAAS-Lemelson Invention Ambassadors. Both authors are part of the AAAS-Lemelson Invention Ambassador team, a program designed to show the human face of invention in order to inspire, inform, and influence everyone about the criticality of invention to the world.

Female inventors—such as the inventor of the Laserphaco Probe, Patricia Bath, and the creator of the A-O compiler and programming language COBOL, Grace Hopper—paved the way for the growing list of women in the AAAS-Lemelson Invention Ambassador program. For example, Lisa Seacat DeLuca (1), a AAAS-Lemelson Invention Ambassador, IBM Master Inventor, and the most prolific woman inventor in IBM's history, holds more than 250 patents, mostly in software development. From 2014 to 2016, DeLuca was named one of the Most Influential Women in IoT, one of MIT's 35 Innovators Under 35, one of LinkedIn's NextWave of 10 Enterprise Technologists Under 35, one of Fast Company's 100 Most Creative People in Business, and IBM's Working Mother of the Year for Working Mother magazine.

When we, as director and advisor, began to create and implement the AAAS-Lemelson Invention Ambassador program (2), it was clear that there was a significant gap in the number of women inventors when compared with the inventive population as a whole. But we held on to the knowledge that women have been inventing throughout history, and their inventions have impacted the world. Since the program's goal is to have invention ambassadors who would inform, inspire, and influence people about the importance of invention, it was clear that we couldn't represent invention fairly unless we embraced inventors in all of their diversity. Because invention is critical in helping to solve global problems, it cannot be afforded to only a few. The more numerous and varied the pool of inventors becomes, the more hope we have of tackling some of our most pressing problems.

As everyone who has ever built a new program knows, it is a monumental task. And it is certain that whenever an application process is involved, most people wait until the very last moment to apply. Therefore, I want you to feel our pain when

we excitedly reviewed the applications for the inaugural class of AAAS-Lemelson Invention Ambassadors only to find that we had only two women apply and no underrepresented minorities. We had distributed the call for applications very broadly and even made personal invitations to ensure diversity of all kinds—fields, race, gender, and type of organization. However, our first class of incredible people—six men and one woman—didn't exactly win us any diversity awards.

Former Under Secretary of Commerce for Intellectual Property and Director of the U.S. Patent and Trademark Office Michelle K. Lee noted in her opening remarks at the “Invention: Does Gender Matter?” roundtable in November 2015 at the University of Texas in Dallas (3) that women are named as inventors on patents at astonishingly low rates. She noted that a working paper entitled “The Lifecycle of Inventors” (4) demonstrates that:

1. The vast majority of patents are issued to men;
2. The share of patents going to women is rising over time, but less than 15% of patents are issued to women;
3. And, at the current rate of convergence, it will take another 140 years for women to obtain 50% of granted patents.

Other research highlights the same gender gap issue in invention. In *The Idea Gap in Pink and Black*, Lisa D. Cook and Chaleampong Kongcharoen note that:

On average, women inventors participate more actively in the drugs and medical field than other U.S. inventors. This observation is consistent with relatively higher shares of women receiving life sciences degrees and relatively lower shares receiving engineering degrees since 1970. The share of electrical inventions among women's patents is six percentage points lower than that of U.S. inventors between 1975 and 2008. The share of chemical patents for female inventors drops slightly over time but is still higher than for that of U.S. inventors. (5)

In the Institute for Women's Policy Research publication, Jessica Milli et al. noted that “[a]lthough women have more than quintupled their representation among patent holders since 1977, only 18.8

percent of all patents had at least one woman inventor in 2010, compared with 3.4 percent in 1977” (6). Furthermore, because there is a close association between a science, technology, engineering, and mathematics (STEM) background and inventing/patenting among men, the study demonstrates that “[w]omen’s low representation in STEM fields plays a role in their low patenting rates, and Black, Hispanic, and Native American women are especially underrepresented among STEM degree holders (7). While increases in women’s patenting are associated with increases in the share of STEM degrees awarded to women, women continue to be grossly underrepresented in some patent-intensive STEM fields, such as engineering and computer science” (6).

ARE THERE WOMEN INVENTORS OUT THERE?

When creating the AAAS-Lemelson Invention Ambassadors program, we couldn’t let these statistics stop us from highlighting that diversity does exist. We wanted everyone to be able to see themselves as potential future inventors. All of the statistics were against us. In “The Lifecycle of Inventors,” Harvard University’s Alex Bell et al. found “that children of low-income parents are much less likely to become inventors than their higher-income counterparts (as are minorities and women)” (4). In addition, the authors note that “[w]e establish the importance of “innovation exposure effects” during childhood by showing that growing up in an area with a high innovation rate in a particular technology class is associated with a much higher probability of becoming an inventor specifically in that technology class (4).

Armed with the knowledge that women patent much less than men (8), we set out on a journey to find women and underrepresented groups who are inventors doing things to solve global problems. The journey is not over.

Where did we start in our quest to find diversity? We started by casting a wide net of opportunity and dialogue. We really believe that a key to increasing diversity is to actually spend a bit of effort looking—not in the usual places you’ve always looked but in the wide world of possibilities that may differ from your normal world. We started by using the diverse advisors we had found; we called friends and colleagues;

we went to conferences and meetings; and we read every invention and entrepreneurship article we could find. While not everyone that we came across had the time or inclination to apply, we became armed with the knowledge of what was and is possible. As time progressed, we became more emboldened in our commitment to increase diversity.

Further, we looked at the history of invention in the U.S., and, because there have always been great women inventors, we knew there were many women breaking down barriers to invent and change the way we interact with our world.

ONE WOMAN ANSWERS OUR CALL

The Invention Ambassador program started in 2014 with a cohort of seven invention ambassadors, and the first female invention ambassador, Karen Burg, (9) was selected that year. Karen’s dedication to the program has been incredible. In addition to her involvement in academia, inventing, and her family life, she remains committed to helping people better understand the importance of invention and ways that others can become inventors.

Dr. Burg is the Harbor Lights Endowed Chair & Professor in the Department of Small Animal Medicine & Surgery at the University of Georgia. One of her inventions is featured as one of ten technologies in the ongoing Avon Foundation for Women–National Institutes of Health–Center for Advancing Innovation Breast Cancer Start-Up Challenge. Her research program has evolved from tissue engineering for regenerative medicine applications to the development of bench-top engineered tissue systems and diagnostics. Technologies from her team’s research have served as the basis for at least one spin-off company.

Burg was inspired by her advisor and serial inventor, Shalaby W. Shalaby, and was determined to make certain that her work makes a difference in the life of others. Her Ph.D. studies and career have led her to understand that innovation lies at the intersection of disciplines and that invention requires collaboration. Burg started her invention career as an engineer working in an operating room. She immediately was struck by the series of surgeries that women with breast cancer had to endure and began trying to come up with better ways to help these women experience

less invasive procedures.

Burg began creating and using injectable engineered tissue systems to help problem-solve in the medical field. Understanding that every breast cancer patient is unique, Burg works to make their treatments just as unique—personalized to their tumors and the tissue that surrounds them. Burg and her colleagues are using a device similar to a 3D printer to create a scaffold on which they can grow a patient's own cells, with tumor cells growing alongside them. She notes that using “tumor cells taken from the patient becomes very powerful and what we call personalized because you're getting information very specific to that individual” (10).

Following through with her belief in the power of multidisciplinary problem-solving, Burg has worked with more than eleven disciplines to accomplish both research and inventions.

BUT ARE THERE ANY MORE?

In the second year of the Invention Ambassador program, we doubled the number of women, which would really be an exciting thing if we had had more than one in the first year. But, by 2017, in year number four of the Invention Ambassadors program, we selected six individuals and one team of two ambassadors—for a total of eight ambassadors, six of whom are women. Twelve of our total 32 ambassadors from 2014 to today are female; an invention program with more than one-third women is significantly above the national percentage of who actually receives patents in the U.S.

In all of our flurry of activity to create more diverse cohorts of Invention Ambassadors, our alumni ambassadors have been incredible sources of recruiting new participants. Our ambassadors are passionate about the AAAS-Lemelson Invention Ambassador vision to showcase the human face of inventors in order to inspire, inform, and influence thought leaders and global communities. If we are going to inspire, we have to see as many kinds of human faces as possible. If we are going to inform and influence, we must have a diversity of voices.

While female inventors are currently less likely to commercialize a patent than male inventors, female invention ambassadors or their students have done just that. Ayanna Howard (11) is one such

ambassador. Dr. Howard's accomplishments have been highlighted through a number of awards and articles, including being named an MIT Technology Review top young innovator and being recognized as one of the 23 most powerful women engineers in the world by Business Insider. Howard is chair of the School of Interactive Computing (IC) at the Georgia Institute of Technology and chief technology officer for Zyrobotics, a Georgia Tech VentureLab start-up company that she founded in 2013. Her research centers on the concept of humanized intelligence, the process of embedding human cognitive capability into the control path of autonomous systems. Howard is licensing technology derived from her research and has released a suite of therapy and educational products for children with special needs.

Jennifer Hall et al notes that “[t]he gender patenting gap is economically very significant: closing the gap among S&E degree holders would increase commercialized patents by 24% and GDP per capita by 2.7%” (8). In addition, we hypothesize that more of our critical problems would be solved by closing this gap. Take, for example, change:WATER Labs, where the Invention Ambassador team of Diana Yousef and Huda Elasaad (12), respectively CEO and CTO, aim to develop and deploy safer, smarter, and more dignified sanitation. The Elasaad/Yousef team is a marriage of invention, technology, water expertise, and business acumen. With their novel approach to toilets and waste disposal, especially focused on women and girls, this AAAS-Lemelson Invention Ambassador duo is tackling a major global issue for people who have no electricity or plumbing. Answering the problem of the 2.6 billion people globally who lack safe toilet access, and the 1 billion forced to defecate openly, change:WATER Labs is developing a technology-appropriate, low-cost, compact, waterless toilet for non-sewered households and communities.

Elasaad has an extensive academic and applied background in the water field. She has professional experience internationally, including Mexico and the Middle East, and in various facets of the water industry, including municipal plant operations for wastewater treatment, desalination, and water process engineering. She is cofounder of PV Pure and consults in the field of commercial aquaculture.

Dr. Yousef is a serial entrepreneur with over ten years of experience in innovating and commercializing technology and novel business models in the cleantech and biotech sectors, pioneering many approaches to translate science and technology into social and environmental impact for the developing world. Yousef was a seed-stage venture investor with Battelle Ventures and Kidd & Company, investing in and catalyzing companies around emerging technologies in cleantech, biotechnology, and information technology.

A common trait that guides many of our invention ambassadors is a passion for making the world a better place. Suzie Pun (13) didn't set out to be an inventor. Dr. Pun was more inclined to see herself as a researcher, a collaborator, and a problem-solver. However, through her research and expertise, as evidenced by her six patents, invention became an avenue for helping others. She sees herself as an Invention Ambassador who represents the teams of people she works with. As the Robert J. Rushmer Professor of Bioengineering and adjunct professor of chemical engineering at the University of Washington, Dr. Pun contributed toward the development of drug delivery vehicles that have entered clinical trials. Her research group has developed methods for drug delivery to the central nervous system as well as injectable, synthetic hemostats for trauma treatment (14). Like Dr. Burg, Dr. Pun credits collaboration and working with people from different disciplines for her success. She notes that her trauma treatment work started with a meeting with an emergency medicine physician who had a problem—injured persons bleeding too much before they could reach the emergency room. The collaborations began and PolySTAT, a polymer hemostat, was born. While the trials are ongoing, the vision is that PolySTAT will be an injectable tourniquet, and the potential applications are many and potentially game changing.

Michele Ostraat (15) works to create a culture of trust and innovation in organizations. Working in application areas such as catalysis, gas separations, and corrosion resistance, she believes that multidisciplinary teams are necessary to create impactful inventions. And while she works to create excellent management practices and incredible teams of people in the development of nanotechnology-enabled

solutions for various industries, her inventions center around using catalysis to convert butane into propylene to make products like diapers, eyeglasses, and packaging materials. Ostraat works to maximize technological innovations with commercial potential in advanced materials and nanotechnology to build industries that have regional and global competitive advantages.

Cook and Kongcharoen (5) note that commercialization behavior among women and African American inventors is closer to that of all other U.S. inventors than previously thought. Like other female AAAS-Lemelson Invention Ambassadors, Dr. Elham Fini (16) is determined to make certain that she is one of the women who invent and become entrepreneurs. She is co-founder of Bio-Adhesive Alliance Inc., director of the sustainable infrastructure materials lab, an associate professor, and a J. W. Fulbright Scholar at North Carolina A&T State University. One of her recently patented inventions is a unique process to break down pig manure and convert it into an asphalt-binding adhesive, an inexpensive, plentiful, and durable substance. Her invention, an innovative bio-adhesive that can be used as either a full or partial substitute to standard petroleum-based adhesives, led to her co-founding Bio-Adhesive Alliance Inc. Having been raised in Iran, a frugal society where little is seen as waste, she is determined to use the natural materials that we find in our communities in unique ways to solve local and global problems.

Like Fini, Dr. Sanna Gaspard (17) grew up in a culture of scarcity in Saint Lucia. She credits her culture for providing her with the tools necessary to become creative and curious and to develop the ability to identify problems and solutions. Gaspard sees opportunities for change in everyday problems. These insights helped her invent a medical device to reduce pre-term infant deaths. Because it has been found that infant massage can help save the life of a pre-term infant, Gaspard invented an automated infant physiotherapy, which automates the infant massage therapy process. She then went on to invent the Rubitect Assessment System to assess bedsores contracted while in the hospital because more than 37 million people get bedsores every year, and more than 60,000 die as a result. Early detection can help reduce or eliminate this \$11 billion cost to U.S. hospitals

every year. When Gaspard reached out to nurses and others in hospitals, she began to better understand all of the issues associated with bedsores. For example, they are very hard to detect with current devices, and the common indicator, skin redness, does not show up on darker skin tones. Further, by interviewing hospital staff, Gaspard was able to understand that the most realistic solution would need to be low cost, easy to use, easy to clean, and easy to store. She designed the Rubitect Assessment System to ensure that there is a device that is easy to use for anyone; able to do skin assessments and monitor changes; able to meet clinical user and technical needs; and low cost. After Gaspard completed her Ph.D., she launched Rubitection. Understanding that invention and entrepreneurship does not happen alone, she created a team to take her invention to market. In the process, she notes that she learned several important things: 1) It's important to create inventions that can truly have impact; 2) it's critical to cultivate the spirit of invention and inspire others to invent; and 3) universities are great places to cultivate the spirit of problem-solving by combining the skill set of the students with resources of the university, such as labs, tech transfer offices, and offerings about entrepreneurship.

ENTICING FUTURE INVENTORS

Karen Burg, Ayanna Howard, and Suzie Pun are all academics as well as inventors, helping to inspire the next generation. Like Gaspard, Ellie Fini believes that inventors are made not born, and they encourage people to aspire to solve problems. Elasaad and Yousef strive to empower women and girls through STEM and innovation. Similarly, Invention Ambassador Elaine Chen (18) says that she found her true passion in life after she started coaching and mentoring students at MIT. She works to demonstrate to students why passion and the need to solve a problem are much more important things to consider than inventing something just because it seems interesting. She pushes students to understand what they really care about. She then insists that they validate the importance of their inventions or proposed inventions with end-users. When a student credited Chen with changing his approach, she realized that her true passion was enabling others to succeed in the

U.S. and globally through invention. Chen says it is worth more than all of her patents put together for her to see students begin to realize their potential and ability to help others.

Invention Ambassadors Maria Oden (19) and Rebecca Richards-Kortum (20) received the Lemelson-MIT Award for Global Innovation in 2013 for their role in the invention of numerous global health technologies, which take life-saving health solutions to the developing world. Their students are key players in their work to provide these solutions. Oden is professor in the practice of engineering education in the Department of Bioengineering and director of the Oshman Engineering Design Kitchen (OEDK) at Rice University. She also co-directs the Rice 360°: Institute for Global Health at Rice, wherein undergraduate students design technologies to address healthcare challenges identified by clinical partners around the world. Oden, as director of the OEDK, collaborates with Rice faculty members to develop and execute engineering design programs for undergraduate students in all engineering disciplines.

Through her work, Oden helps students take on real world problems through collaborations and partnerships with university researchers, industry, community partners, and the Texas Medical Center. She gives students the inspiration, knowledge base, and opportunity to become inventors. Oden, along with faculty colleagues like Richards-Kortum and students in her classes, has invented many technologies, including the bCPAP system to help premature babies breathe, a syringe pump, an apnea detection and correction monitor, medication dosing clips, a blood pressure monitor for pregnant women, and an infant incubator. Further, Oden is credited with incorporating engineering design and invention into the curriculum of the George R. Brown School of Engineering, giving students the opportunity to invent as early as their freshman year.

Dr. Richards-Kortum has established new educational programs at Rice University in global health technologies. She founded the Beyond Traditional Borders (BTB) program, which helps undergraduate students from a variety of backgrounds learn to think beyond geographic and disciplinary boundaries to solve challenges in global health. In 2012, Science awarded BTB the Prize for Inquiry Based

Instruction, which recognizes outstanding examples of inquiry-based and design-based engineering education modules.

CONCLUSION

Invention is a necessary precursor to innovation, and innovation brings us the ability to solve problems and create advances in all fields. There are ways to bring more females and other underrepresented groups in to this ecosystem, and our ability to solve world problems depends on our ability to attract more and diverse people to the worlds of innovation and problem-solving. More diverse teams develop more diverse solutions to a wider range of problems. It is disappointing to think that women hold less than 25% of STEM jobs in the U.S. despite the fact that they fill close to half of all jobs in the U.S. economy. Additionally, women have a 50% attrition rate in STEM careers during their first twelve years on the job, compared to only 20% of professional women in non-STEM fields. If we want to continue out-innovating and out-performing our economic competitors in the global economy, we cannot compete with one hand tied behind our back due to the low numbers/retention of women in STEM fields, particularly in engineering (8), and the lack of female inventors. There are many ways to increase the numbers of underrepresented groups in the invention ecosystem. The federal government, nonprofits, industry, and individuals are all critical players in seeking this increase. While we have already mentioned the role of the AAAS-Lemelson Invention Ambassador program, some of our program's partners are actively working to increase innovation, entrepreneurship, and inclusivity in invention.

Over the last few years, the U.S. Small Business Administration's Office of Investment & Innovation (SBA-OII) has been ambitiously tackling issues surrounding the nexus of technology, innovation, and inclusiveness. The SBA is a collaboration with the eleven participating SBIR-focused federal agencies. Some of the AAAS-Lemelson Invention Ambassadors have harnessed the power of SBIR, including Karen

Burg, Ellie Fini, Sana Gaspard, and Ayanna Howard. The National Institute of Standards and Technology (NIST) has a science and technology entrepreneurship program to provide researchers working at NIST support for exploring entrepreneurial careers. The program is designed to bring technologies related to the mission of NIST to the commercialization stage in order to benefit the public. And the National Science Foundation (NSF) has created the I-Corps program to move basic research projects toward commercialization and prepare scientists and engineers to accelerate the societal and economic benefits of NSF-funded basic research projects.

The U.S. Patent and Trademark Office (USPTO) promotes and protects American innovation and supports this objective across all geographic regions of the country and across all demographics. The USPTO, through its educational outreach to "K to gray" audiences, promotes and encourages the participation of girls and women in STEM careers and as inventors and innovators, and they host a wide variety of programs to support these efforts.

The USPTO, like its collaborators at the SBA, achieves a great deal through cooperation with other organizations, programs, and state and federal government entities. One good example of a long-standing collaboration is the USPTO's joint project agreement with the National Inventors Hall of Fame, which works to honor those diverse inventors who have revolutionized our world and offers inspiration to young inventors from preschool levels to graduate students in their Collegiate Inventors Competition.

University programs, like Rice University's OEDK described in this article, encourage invention, as do programs like VentureWell <https://venturewell.org>. The Lemelson Foundation, guided by the belief that invention and innovation are essential to economic success and vitality, provides funding to inspire and educate the next generation of inventors. People and organizations too numerous to name are working to increase diversity and inclusivity in invention. Tackling global problems depends on it.

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