11

A GENDER PERSPECTIVE ON TECHNOLOGY TRANSFER AND WEALTH CREATION

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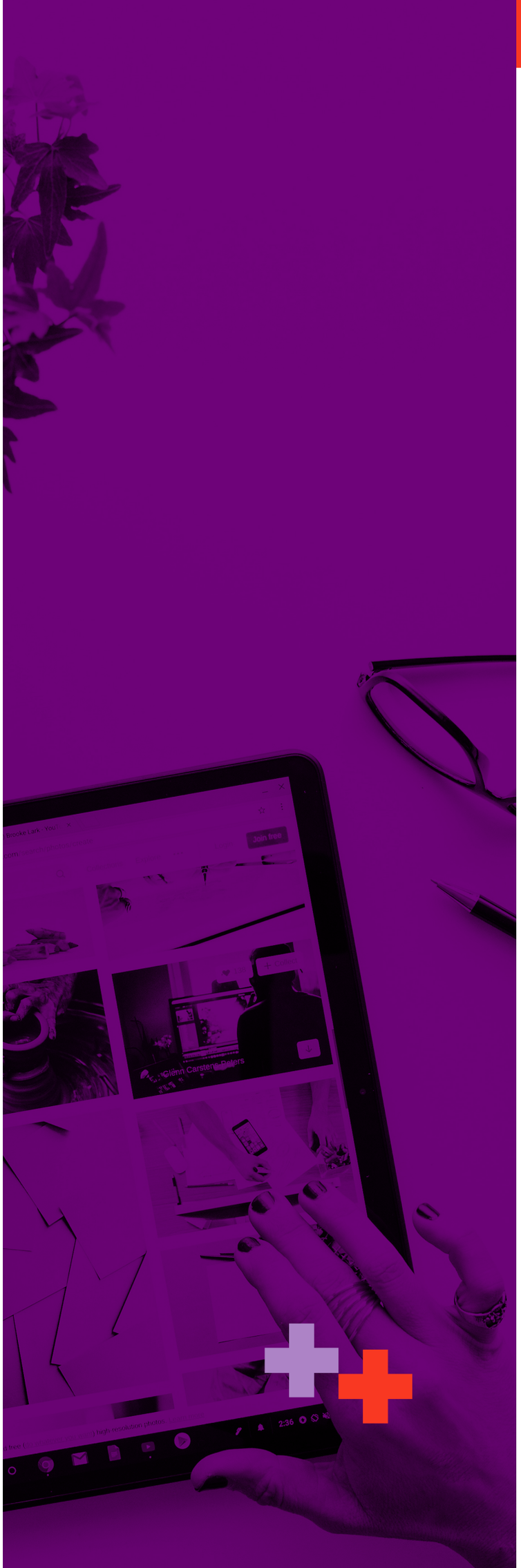

ABSTRACT

More than 40% of the world's population now has access to the internet, with new users coming online every day, while today the poorest households are more likely to have access to mobile phones than to toilets or clean water. In spite of these advances in technology, many are left behind from the wealth creation spurred by new technologies in the innovation economy. A new wave of innovation has the potential to give women a unique opportunity to reap the advantages of wealth creation from the digitised economy, to leverage women's potential for technical innovation and to create new female ecosystems linking science, start-ups, and industry. Alternatively — as seen in the gender digital divide more broadly — this new wave of innovation could leave female inventors behind. "Technology transfer" refers to the process of developing and commercialising innovations, as typically reflected in intellectual property rights, patents, and copyrights. Supporting girls' digital literacy through the entire educational spectrum of science, technology, engineering, and mathematics (STEM), including participation in research and development and ultimately technology transfer, is a long-term investment that could potentially result in an exponential increase of wealth creation for women. This chapter examines the current patent shortage among women, and explores how social innovation and support from NGOs and global development organisations can work to make tech-transfer more gender inclusive. We need to be as ambitious in support of gender equity in technology transfer as in STEM education and workforce development.

KEY FINDINGS

- Women with STEM degrees are only slightly more likely to patent an innovation than women who lack them.
- The most significant determinant in the gender gap in technology transfer is women's underrepresentation in patent-intensive fields (especially electrical and mechanical engineering), and in patent-intensive jobs (especially development and design).
- The lack of gender-disaggregated data for technology transfer (such as patents and copyrights) reflects the absence of any global organisation to track trends in gender balance in tech transfer.
- Virtually all indicators related to gender balance in the World Intellectual Property Organisation Patent Cooperation Treaty (PCT) or patent system show some degree of progress toward gender parity in recent decades.
- Based on current rates of progress, gender balance in patenting would not occur until 2070.

INTRODUCTION

Technology transfer (tech-transfer, or TT) represents the successful transformation of good research into good business, according to Alunni (2019), as well as the formal and informal movement of know-how, skills, technical knowledge, or technology from one organisational setting to another (Roessner, 2000). Both sources point to the importance of tech-transfer in aligning stakeholders to support researchers/inventors in the daunting project of moving a protected idea (i.e., intellectual property) successfully into the market. TT has become central in university research, and it presents challenges and opportunities — both for individual inventors and for efforts to address old and new problems.

A successful TT process needs four essential elements: 1) strong research to generate a sound IP portfolio; 2) a dedicated supportive Technology Transfer Office (TTO), as a meeting point of science and business; 3) a team of highly skilled Technology Transfer Managers (TTMs) who understand the languages of science and business; and 4) an entrepreneurial ecosystem capable of absorbing innovation and providing ancillary services (Sharma, Kumar, & Lalande, 2006). Additionally, these resources must be available at the right level and must be managed efficiently.

Experts of the field proclaim that human progress is manifested and occurs through use of technology and that without technological progress there would be no economic development. However, as Jacobsen (2011) observes, while human progress cannot occur without technological innovation and diffusion, it is unlikely that technology affects all groups and genders equally.

WHY IS TECHNOLOGY TRANSFER IMPORTANT FOR GENDER INEQUALITY?

As technological innovation and diffusion accelerate, little attention has been paid to the potential social impact of equality for technology transfer and wealth creation. One of the main challenges in the complex process of commercialising intellectual property (IP), according to EUIPO, is that the great majority of ideas (whether protected or not) never make it to the marketplace (Campinos, 2018). Experts on feminism and technology point to the scant proportion of women obtaining patents globally, which is even less than the already small proportion of women in the field of STEM (Rosser, 2009).

The question of gender in technology transfer can thus be usefully addressed on two levels: How does technology transfer work in practice? And how are women either involved in or excluded from

the process? Literature on technology transfer and innovation can shed light on how prominent centres of research (as well as leading intellectual property bodies) attract women innovators and how existing mechanisms affect women's involvement or exclusion in technology transfer.

Some researchers point to a lack of diversity in the process of developing new technologies, and to the lack of commitment by prominent research centers to attract women inventors. Only 15% of patents are filed by women (Jensen, Kovacs, & Sorenson, 2018). Others point to gaps in relevant skills and impact funding at the early stages of proof-of-concept, prototyping, and demonstration (Alunni, 2019).

Missing in the literature is a critical analysis of technology transfer in terms of gender. While feminists have questioned the implications of the low percentage of women in STEM for our understanding of gender in innovation (Schiebinger, 2008), there is less work on the gendered implications of current technology transfer implementation (Phan & Siegel, 2006), although the issue of implicit bias in technology transfer has long been recognised. Writing over 30 years ago, radical feminists and ecofeminists initiated a critique of the inherently patriarchal nature of technology, and of technoscience more generally, questioning "best practices" that themselves may be flawed (Oakley, 1974; Cockburn, 1983; Corea et al., 1985; Kramarae et al., 1988; Wajcman (1991) as cited by Bray, 2007).

KEY CONCEPTS: HOW DO TT AND GENDER INTERCONNECT?

The development of technology draws upon many fields of knowledge — scientific, engineering, mathematical, linguistic, and historical — to achieve some practical result (Pacey, 1992). Technology transfer is not a novel concept: it can be defined as an emerging process going back to the mechanical age (Bessant & Rush, 1995). Nevertheless, it would take many centuries after the first patent legislation in Venice in 1474 (Penrose & Zamora, 1974) for European and U.S. universities to begin to bring new inventions to society. With the enactment of the Bayh Dole Act in 1980, U.S. universities started to patent and license scientific discoveries. Since then, technology transfer has evolved to become a political and corporate mantra, promising significant change based on both better and more technology (Slaughter & Leslie, 1997).

The goal of technology transfer is to take sound scientific ideas to the market successfully (Bercovitz & Feldman, 2006). It is important to understand how technology transfer works in practice, to help women inventors protect their scientific ideas and increase their participation in the process.

Two complementary aspects are critical in increasing the role of women in the development of new technologies. First, university policies need to attract, support, and reward women inventors. Second, the barriers need to be addressed that may prevent female inventors from commercialising their scientific ideas or inhibit their professional advancement. If female inventors are accorded unbiased support to protect and prototype their scientific ideas, technology transfer will play a part in increasing gender equality.

Young (2007, p. 545) posits that "technology transfer does not just happen". Transferring knowledge and innovation from a public research organisation to the private sector for commercial application and public benefit requires a formal mechanism — a technology transfer office (TTO) — to help inventors protect and license intellectual property. In order to promote inclusive innovation, this mechanism must be unbiased and committed to support men and women inventors equally, in each stage of the process (Siegel, Veugelers, & Wright, 2007).

The rapidly changing landscape of innovation requires a major effort to equip female participants (scientists, engineers, researchers) with the necessary resources (such as TTOs, incubators, accelerators, and service providers) to ensure their success. Moreover, women need not only training and qualifications to shape the right skills, but also accessible mechanisms for funding in the crucial proof-of-concept and demonstration phases (Etzkowitz & Goktepe-Hulten, 2009). The traditional activities of technology transfer offices (TTOs) include identifying promising research results from the university setting and transferring them to market agents. A TTO depends on access to an active university and researchers, industrial absorptive capacity, and investors. TTOs serve effectively, bridging these three factors, only when they are able to provide the missing pieces in the technology transfer process. A passive TTO may fail in the mission to promote technology transfer.

Advanced TTOs are mainly attached to more entrepreneurial universities in high-income countries; they offer effective support to researchers, inventors, and entrepreneurs by taking a proactive role to help them to cross the "valleys of death" in the process of starting a new venture. World-class TTOs normally offer ten standard support services: invention disclosure, invention assessment, idea protection, proof of concept, IP commercialisation, start-up formation, licensing to existing business partners, legal support, commercialisation after licensing, and licensing revenue distribution (Debackere & Veugelers, 2005). This expensive and time-consuming process has become a high priority on university policy agendas, as the key to effective technology transfer mechanisms.

IS TECHNOLOGY TRANSFER GENDER-NEUTRAL?

For many people, technology transfer has no implication for gender, suggesting that TT is therefore gender-neutral. In fact, gender-based disparities have been found in many areas of technology transfer, though the mechanisms are often still little known.

Successful women professionals, in science, technology, and allied fields, tend to refer to meritocratic ideologies rather than structural factors to explain inequality (Cech & Blair-Loy, 2010). Business education experts are likely to invoke deficiencies in women's human capital or motivation, even though systematic structural obstacles (such as glass ceilings) are widely considered the main cause of gender inequality in science and technology (Tan, 2008).

One source of structural bias lies in unequal access to university support. In emerging science and technology-related areas, women's participation, advancement, and recognition often seem to suffer from the same discriminatory gender patterns identified elsewhere in academia (Etzkowitz, Kemelgor, and Uzzi, 2000). The Women Inventors Committee of the Association of University Technology Managers' (AUTM) states that the professionals working across continents to facilitate technology transfer all share one common challenge: a lack of women's participation in several aspects of the process (WIC, 2018). The Association attributes this gap to the lack of university commitment to educate female university scientists about the impediments and barriers women face when attempting to become inventors and entrepreneurs. The report suggests action steps toward the goal of including more women scientists and engineers in successful technology transfer and business creation.

In the university environment, there are no explicit rules that position men and women inventors differently. The slow progress toward gender equality nevertheless reflects obvious discrimination and invisible barriers built into male-gendered systems (Ranga & Etzkowitz, 2010). For example, discrimination against women scientists, researchers, innovators or entrepreneurs occurs when — by default — men are over-ascribed for performing traditional female roles and women are under-credited for performing traditional male roles. Ranga and Etzkowitz also observe that most efforts for gender equality tend to focus on women's recruitment rather than retention and advancement, reflecting false expectations that upward movement would take care of itself once entry was assured. It comes as no surprise that disproportionate numbers of women remain in low-level positions in academia, even after many years of contributions. Handelsman et al. (2005) suggest that universities are failing to take advantage of an available resource, noting that the presence of women scientists in a particular field determines the proportion of women in faculty positions, and that this ratio lags far behind the proportion of Ph.D.s granted to women. They identify, as reasons for this disparity, the impediments to recruitment, retention, and advancement of outstanding women scientists. Similarly, AUTM suggests that many of these barriers reflect unconscious bias by all involved in the system, including the women faculty members themselves; the Association seeks to educate female inventors and relevant institutions to address these goals. It further recommends empowering more women to take leadership roles in all stages of transferring new discoveries to the market (WIC, 2018).

Several mechanisms have enhanced women's involvement in TT. In 2011, MIT instituted an awards programme called ADVANCE, at a funding level of $19 million, to support efforts by institutions and individuals to empower women to participate fully in science and technology. The Institute cited an "increasing recognition that the lack of women's full participation at the senior level of academe is often a systemic consequence of academic culture" (Rosser, 2003, p. 6). This programme led to a common statement by nine U.S. research universities, recognising that institutional barriers have prevented women scientists and engineers from having a level playing field in their professions; the signatories were the California Institute of Technology; MIT; Harvard, Princeton, Stanford, and Yale universities; and the universities of Michigan, Pennsylvania, and California, Berkeley.

Many of the studies of technology transfer processes and implications focus mainly on the prominent research centres in high-income countries (such as Harvard and MIT in the U.S., Oxford and Cambridge in the UK, and institutes in Japan, South Korea, Israel, and others). Research is badly needed to examine the global implications of boosting women's participation in wealth creation through research discoveries and knowledge transfer to industry.

A second source of gender bias arises from the structural constraints of the IP filing system, including how patents are obtained and maintained over time. Jensen, Kovács, and Sorenson (2018) analysed a recent IP filing bulk data release with the histories of 2.7 million patents issued in the U.S. between 2001 and 2014. Their analysis reveals how patent claims can be altered during the process of filing, depending on the gender of the inventors. Overall, women inventors' patents were more likely to be rejected than those filed by teams of men; even when applications were granted, women's patents progressed poorly and fewer were maintained, because they received fewer citations by other inventors and from patent examiners (Jensen, Kovács, & Sorenson, 2018). This helps explain why, although women earn roughly 50% of the doctoral degrees in science and engineering in the U.S., when it comes to patenting their inventions, they trail far behind men: only 10% of patent-holders are women. Even in the life sciences, where women earn more than half of new Ph.D.s, only 15% of inventors listed on patents are women.

Rosser (2009) argues that, if women scientists and engineers face difficulties in obtaining patents, then woman are not equal participants in the newest areas and of science and technology; they are unable to serve as leaders in their fields, and they lose opportunities to profit both financially and through professional advancement. Of course, commercialisation of science can be extremely lucrative, if the patent results in a product that is developed and brought to market successfully. Research is therefore in order to find ways to mask the applicant's identity and gender. One potential solution would be to make the IP filing process more anonymous, for example by listing only the inventors' initials; further exchanges between the applicants and the examiners could be restricted to a platform that ensures anonymity.

Creating an equal playing field in the patent process will not only benefit women. Technical progress is one of the primary drivers of economic growth, and it is boosted when inventors can lay legal claim to their innovations and profit from them, and when others can build on an existing patent. Increasing fairness in the patent system, and thus bringing more good inventions to realisation, has the potential to create wealth and promote economic development.

A third source of bias is embedded in the financial environment. Registering and protecting scientific ideas as intellectual property (IP) is an essential step toward marketing an invention, but it is only the beginning of the process. Regardless of their potential, many scientific ideas — up to 95% in the U.S. — never progress beyond this protection or patenting stage. Proof of concept (POC) is usually the next step toward marketing, allowing the inventor, as well as potential investors, to identify marketable value in a timely fashion. Funding for POC helps inventors to prototype the idea and show prospective clients a real version of the product, before commercialisation (Upton, 2010).

As useful as POC and prototyping can be, investors tend to be reluctant to fund prototyping ventures (Portilla, Evans, Eng, & Fadem, 2010) — a factor that also affects female inventors. In general, even though POC is vital to a successful tech-transfer process (Alunni, 2019), it is the least attractive phase to private finance, despite the small amounts required per project. Providing POC is therefore a difficult task for most technology transfer offices, especially on behalf of female inventors. Hill, Leitch, and Harrison (2006) show that women get a small fraction of the venture capital allocated to men; despite heightened attention to the problem, the newest data suggests the problem could be getting worse. Indeed, Bosse and Taylor (2012) suggest that a "glass ceiling" prevents women entrepreneurs and small business owners from accessing the financial capital they need, to start a new firm or fuel the growth of an existing small firm.

Moreover, embryonic scientific ideas usually need further development before they can be fully protected as intellectual property in any form (by patents, copyright, etc.). This early process normally has costs, and although the amounts are not large, they may prevent women from advancing the idea to the POC phase. Universities and other innovation agencies could provide impact acceleration funds to support this essential step for women inventors. Significant research has been carried out through the U.S. government's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programmes. All federal research and development (R&D) grants to technology ventures for the decade 2001–2011 were tracked by grantees' demographic classification, to assess demographic patterns in successfully obtaining follow-on R&D grants. The study analysed 52,126 initial (Phase I) awards, granted by 11 federal agencies through SBIR/STTR, which might or might not be followed up with a Phase II award. Results showed a positive association between agency workforce diversity and Phase II funding for women Phase I grantees; however, minority and women technology entrepreneurs were less likely to receive Phase II funding than their non-minority and male counterparts. A preliminary conclusion indicates that the agencies that value workforce ethnic diversity were more likely to grant women technology entrepreneurs Phase II funding. Mollick and Robb (2016) observe that women with higher levels of education may increase their likelihood of obtaining funding, but they also argue that, in the initial "bootstrap" phase, utilising social capital may improve women's chances.

Indeed, researchers and TTOs in high-income countries are already trying to address the problem of finance to advance more women's scientific ideas to the market. In 1999, the Oxford University Innovation TTO set up early-stage funds for POC applications using a gender-unbiased funding mechanism, called the Oxford University Challenge Seed Fund (UCSF). It has provided funds of over £8.2 million across 150 projects from 200 applications — successfully using this unbiased mechanism to award similar levels of funding for projects led by male and female applicants (Alunni, 2019).

The advantages from such gender-friendly funding mechanisms go beyond generating value from tech-transfer; the potential benefits also include diversity for excellence, follow-up grants, industry-sponsored research, and an enhanced reputation, as well as broader educational experience through working relationships with female-led start-ups and SMEs (Cronin, Prakash & Mehta, 2015). Social inclusiveness becomes especially relevant for TTOs with a longer investment time horizon, to align with university vision and to promote growth through equal participation opportunities for male and female scientists.

CAN TT BENEFIT WOMEN?

Despite the role women play in job creation, economic growth, and society revitalisation, especially in economies undergoing fundamental transformations, women in entrepreneurship have not received adequate attention in academic research (Tan, 2007). As a result, our understanding of women's opportunities in non-traditional industries is limited.

Broader innovation depends on a concerted effort to share skills, knowledge, technologies, and facilities, through gender-unbiased mechanisms, ensuring that novel ideas become accessible to a wider range of users in the form of new products, processes, applications, materials, and services. Research findings, skills, expertise, and technology must be transformed into repeatable processes, products, and programmes to fuel wealth creation and benefit consumers (Grosse, 1996).

A new wave of technical innovation will bring huge opportunities to women in global industry. Some refer to Industry 4.0, or "deep tech", or (in Japan) Society 5.0. All envision a merging of physical and digital technologies that will fundamentally change most, if not all, industrial sectors. As suggested by Heeks (2008), the next innovation wave presents a unique opportunity for women in industry: to leverage women's science and technology potential and to create new gender-friendly ecosystems comprising science, start-ups, and industry. For this next wave of innovation, women's scientific strengths will be a huge asset.

Two social innovation projects illustrate this potential.

A civil engineer and her business partner from the Gaza Strip found a way to turn ash into bricks. These bricks are eco-friendly and affordable, and they use less cement than regular bricks. The innovation helped solve a local problem for thousands of people after losing their homes.

The GlamOre digital platform was created by graduate students at Oxford University, out of the belief that talent is equally distributed but opportunity is not. The platform gives women opportunities to work for international companies, by sourcing data projects for some of the world's largest commodity companies. GlamOre is a pioneer in the field of impact sourcing — the practice of hiring people from the bottom of the pyramid to enter digital work, with the help of established professionals.

Innovations such as artificial intelligence, biotech, and two-dimensional materials all require cutting-edge science, based on "all-hands-on-deck" diversity. We need to be as ambitious in technology transfer as in teaching and research. This is in line with the increasing emphasis on supporting creativity, as part of the United Nations agenda for "smart, sustainable and inclusive growth" (Cooke & De Propris, 2011).

Gender biases in the technology transfer process have not received adequate attention by ancillary institutions, prompting proposals to create a Global Female Innovation Council (GFIC). The council would operate as a Global Technology Transfer Office, providing assistance to female inventors who are interested in presenting scientific ideas for IP filing or commercialisation. In addition, it would serve as a safe and confidential channel for advancing innovative ideas, without fear of IP theft — a major deterrent for new inventors.

To generate global wealth with strong female participation, it is necessary to foster education and inclusiveness across countries and continents. Innovation more than ever requires female talent, motivation, and new skills to generate valuable ideas to tackle global problems. Untapped female resources should be channelled in all ways possible between science and business to reach optimum social benefit (Ong, 2005).

RECOMMENDATIONS FOR POLICY MAKERS

Supporting gender inclusion in technology transfer cannot be achieved by the sole effort of universities (Rampersad, Plewa, & Troshani, 2012). Other stakeholders, such as venture capitalists, business angels, alumni, industrialists, and other professionals, should be engaged to identify and nurture gender inclusion in technology development.

A handful prominent universities have developed initiatives to attract women and reward institutions working to increase women's involvement. However, most universities in both developed and developing countries still lack a well thought-out support programme (AUTM, 2018). More broadly, STEM fields in education need to become more inclusive of women.

There is a need to create more gender-diverse networks to pool talents, knowledge, money, and ideas. Professional women can be encouraged to develop networks around tech-transfer management, as a high-value profession for female scientists. Addressing the gender gap in decision-making positions may require a new generation of female technology transfer managers (TTMs) with business school background. These new leaders may help to build consensus to establish a Global Female Innovation Council (GFIC) and to build trust in women's potential role in technology transfer.

To get more women involved in the process of technology transfer at every level — from idea generation, through research and discovery, to patenting and licensing to new or established companies — these ideas should be considered:

- Women in tech can be socialised in TT via classroom learning, e-learning tutorials, and training workshops, reinforced with internships and mentoring to help them build working relationships and career prospects.
- Women's qualifications can include socialisation into different cultures (academic or business) and learning through experience.
- Women participating in the technology transfer process need a fuller understanding of the challenges in the IP filing process; they may need to campaign for better support to neutralise existing barriers.
- Universities should encourage and support promising female innovators to share their ideas, and help to mitigate the risk involved — particularly if they are radically innovative and have the potential to scale internationally.
    - Initiatives to encourage idea-sharing include informative campaigns, summer workshops, mentorship, and networking.
    - Trainings can use open data to allow those giving and receiving training to share information on policies and procedures and suggest improvements.
- An idea conceived at the first EUIPO workshop on technology transfer (2018) is to create a clearinghouse, specifically to identify and track female talent.
- Dedicated government policies are needed to encourage unbiased financing schemes to incubate female-driven technologies before venture capital firms and other investors become interested.
    - Provide impact finance to support ideas presented in scientific papers or early IP filings, to facilitate women's engagement in the TT process.
    - Universities and other innovation agencies could provide impact acceleration funds to support prototype development by women inventors.
    - Conduct research on the constraints that disproportionately affect women in attracting private sector funding for the POC process.
    - Focus on start-ups and small and medium enterprises (SMEs), strengthening the tech-transfer scientific ecosystem where the greatest potential for female breakthrough innovation lies.

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