

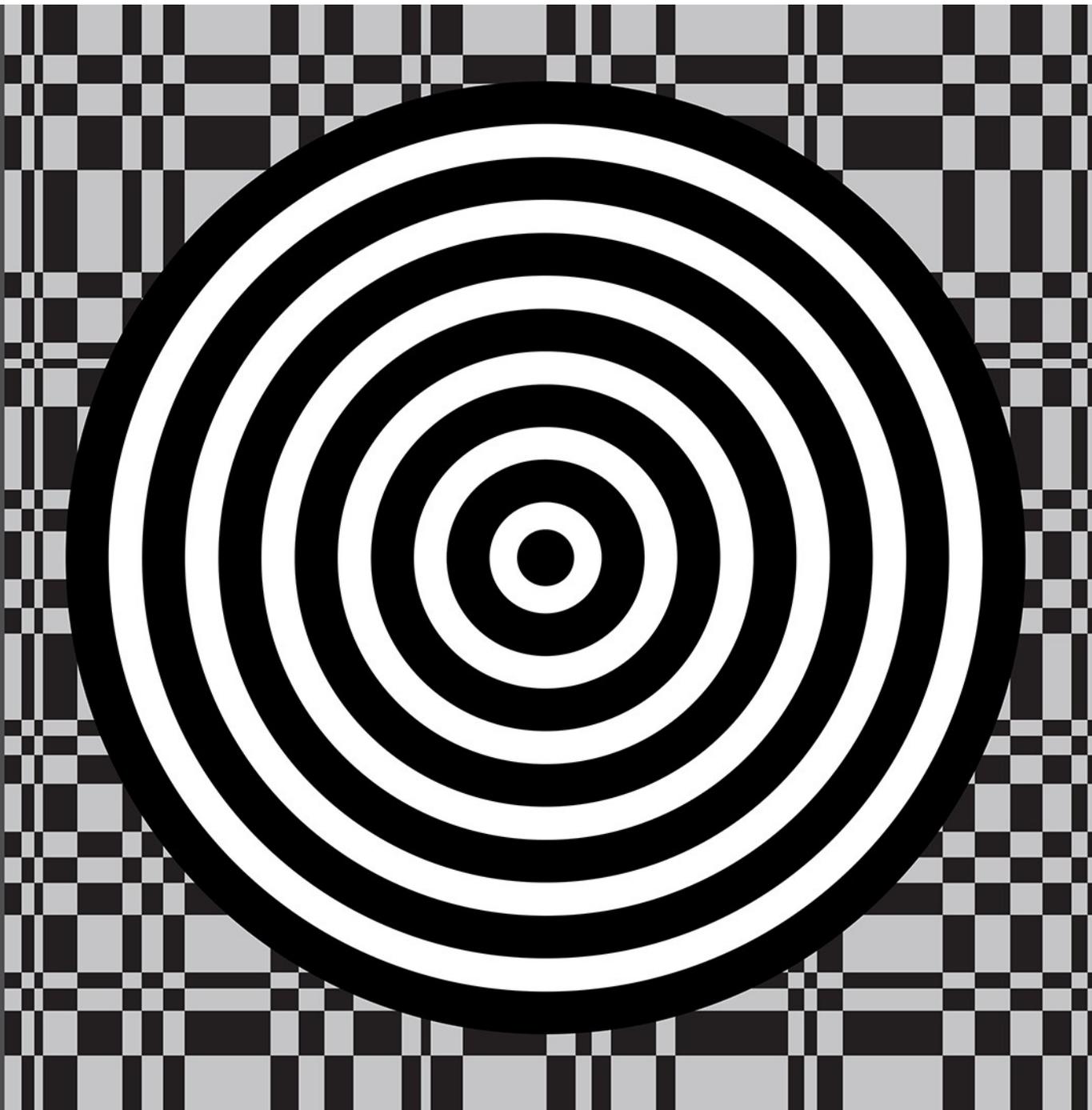
Research Synthesis 6

Historical Perspectives and Future Scenarios

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Why explore the history and futures of gender and Science, Technology and Innovation?

Science, technology and innovation do not exist in a vacuum, but take place in historical contexts. Similarly, the question of science, technology and innovation (STI) in the future needs to be understood as located socially and historically. Accordingly, a historical perspective on gender and STI is pertinent in order to understand adequately gendered patterns and relations in both the past and the future: *who does science, technology and innovation? How are science, technology and innovation organized? And also, how is knowledge constructed in science, technology and innovation?* These are three key components of the relationship between gender and science and technology, as identified by, amongst others, Schiebinger (1999) and Hearn and Husu (2011). The first two of these issues are now well examined and established; the third of these issues is the least explored and the most far-reaching in its implications.

On the first count, we note that in 2011 women in the EU made up roughly 33% of researchers in all sectors (She Figures, 2012). The figure remains at 33% in 2012 (She Figures, 2016). Research shows how women continue to be under-represented in the upper echelons of academia; in 2010 in the EU-27 women comprised only 20% of grade A academics, and 21% of Grade A academics in the EU-28 in 2013 (She Figures, 2016). Horizontal segregation persists, for example, in 2010 in the EU-27 women accounted for 64% of PhD graduates in education, and 63% in 2012 in the EU-28 (She Figures, 2016), whilst only 26% of engineering, manufacturing and construction PhD graduates, and 28% in the EU-28 in 2012 (She Figures, 2012, 2016).

In terms of the second issue, the organisation and management of science, an important question concerns both the gender structures, processes and practices within those organisations, and people's positions on gender equality and gender issues more generally. These latter positions may range from very strong principled support for gender equality to outright opposition. A related key area concerns the different gendered ways of being managers and doing management (what might be called managerial masculinities and managerial femininities) that there are done in science and science organisations, in terms of action, promotions, scientific priorities, the distribution of scientific resources, and also importantly for some the transition from being primarily a senior scientist to being primarily a manager of a science unit.

A linked issue is how do men, and women, in science and science management relate, in gender and other terms, to each other, for example, how do men-men relations, men's networks, male bonding, homosociality (as in men recognising, preferring and valuing men and men's company over women and women's company) (Lipman-Blumen, 1976) and "cultural cloning" (Essed and Goldberg, 2002) work within and between science institutions.

Regarding the third question, the scientific method may be thought of as an objective means of analysis that operates independently of values or personal bias. In addition, this method is widely assumed to be independent of patterns of resourcing, for example, support for and sponsorship of early careers, and allocation of grants and other research resources, which are often highly gendered, bringing possible differential impacts on research, especially if and when men and women tend to specialise in different areas. However, despite the success of this unitary scientific model, this view of science is challenged on various fronts

"... notably by feminist-based scholars (e.g. Keller 1985; Schiebinger 1999), who have argued that science actually reflects a masculine bias as a means of collecting knowledge. Rather than being completely objective and value-free, the scientific method, as typically defined, reflects hegemonic masculinity and the subordination of femininity. The masculine bias in science is expressed in its sexist language, masculinist structure and methodologies, and androcentric epistemology (Letts 2001). There is a correspondence between stereotypical masculine traits and the definition of the scientific method. Masculinity is associated with competitiveness, dominance hierarchies and logical, as opposed to emotionally driven, thought. The scientific method can be seen as the valuation of the same attributes." (Beggan, 2007)

Whilst it is commonly accepted that power is a key mediating concept, the question of how gender, science, technology and innovation interact is subject to much debate (ibid.). On the one hand, "science and technology are not just structured by gender but pervaded and constituted by and through gender. At the same time scientific and technological realities construct, and sometimes re-form and even subvert, dominant gender relations" (Hearn and Husu, 2011:103). Evelyn Fox Keller argues that the relationship between gender and science reveals "the deep interpenetration between our cultural construction of gender and our naming of science" (1992:47).

In discussing gender and science, technology and innovation, whether through a historical lens or not, limited conceptualisations of gender are often in use. When talking of the gender dimension in science, as in many other fields, the notion of “gender” is often interpreted to mean “female” or “women”. To understand the gender dimension involves developing an understanding of men and masculinities, as well as women and femininities. Men and boys are just as gendered as women and girls. The perspective of seeing men as gendered is much less researched in relation to the practice and research process of science. Science is often viewed as implicitly or explicitly done predominantly by men, who are then constructed as non-gendered or as an invisible gender, while women are seen as entrants into the activity of science, and are explicitly gendered, or even sometimes seen as equivalent to gender. This kind of view is itself an example of the gendered construction of knowledge. In order to understand the gender dimension it is necessary to understand gender relations, including gender relations between women and men (Kimmel et al., 2005). Arguably, simplified understandings of gender are sometimes, but far from always, problematised in relation to the future and the future development of gender and STI.

So how does a historical, future-orientated or more general temporal view of the relationship between gender and science, technology and innovation help us to understand better this broad field? Taking a longer term perspective can enable us to identify recurrent and persistent gender patterns and images and may provide useful insights into analytical categories *per se*, the processes of identifying and deconstructing power *relations* as well as providing tools to examine how knowledge is produced.

At the same time, considering the relations of gender and science in terms of future trends and possibilities is also increasingly becoming an important focus of attention. There are multiple issues here in the field of gender and science, ranging from forecasts of labour market shortages in STEM, or even the need for far less people working in such fields, to technological scenario development, to re-imagining the changing relations of gender and science, whether gender-neutral or gendered/sexed in new ways. All these cases raise challenges for the science policy agenda and research landscape.

Considering the histories and futures of gender and science alongside different conceptions of gender that shape the policies in this field provides a fruitful framework for analysis. For example, Hearn and Husu (2011) identify five different

'underlying formulations' that 'inform both policy interventions and theorizing around gender and science: gender based on sex; masculinity/femininity/ and sex roles; categoricalism, structure and plural structures; poststructuralist, discursive and deconstructive approaches; and the material-discursive'. These approaches can be seen to influence research perspectives and policy interventions in this field.

Men, women and science: roots and patterns in social and cultural inclusion and exclusion

A historical examination of exclusion, inclusion, representation, the forgetting of and obscuring women in science – may contribute to explain partly the current gendered patterns of participation. Gendered patterns of social and cultural inclusion and exclusion in science can be traced throughout time. The history of science is often presented as the history of great men. Thomas Beggan (2007) summarises this approach, albeit critically, as follows:

“The modern scientific method was first described by Sir Francis Bacon (1561–1626) shortly after the end of the Renaissance (1450–1600) in The Advancement of Learning. The goal of the scientific method is to develop theories, derived from empirical evidence, that explain phenomena and allow for the prediction and control of the external world. ... the scientific method has been remarkably effective in transforming the way we examine and interact with our physical world. [...] Sir Isaac Newton (1643–1727), illustrated the power of science in two incredibly productive years when he began revolutionary advances in mathematics, physics, optics and astronomy. His Principia, considered the most important scientific book ever produced, presented laws that applied to falling objects on earth as well as the motion of the planets and comets. These principles are essential to understanding applications ranging from the firing of cannon balls to the orbits of rockets in space. Working in a different domain, Gregor Johann Mendell (1822–84) examined how traits are passed from one generation to the next. Although he was unable to explain the mechanism of genetic transmission, his identification of dominant and recessive traits could be seen as the basis for current research on cloning and genetic testing. Modern medical miracles such as heart transplants and life-saving drugs like antibiotics have been made possible by the exercise of the scientific method.” (Beggan 20007, p.543)

Women may appear newcomers in science, but in fact, female scientists have been traced back to at least 4000 years ago (see, e.g. <http://www.astr.ua.edu/4000WS/>). The institutional structures of science, the contexts where science has been pursued,

have always had an impact on women's opportunities to engage in scientific activities (Schiebinger 1987:316). In the 1660s the Royal Society of London and the Académie des Sciences in Paris were established and explicitly excluded women practitioners (Abir-Am, 2010:154). Two hundred and fifty years later Marie Curie, despite being the first person to win two Nobel prizes, was denied membership to the French Academie des Sciences in 1911 (Crasnow et al., 2015). This pattern of exclusion was reproduced – and multiplied as women continued to be excluded from a wide range of scientific institutions that were set up, including national associations to advance science and academic departments, societies at the disciplinary level and provincial academies (Abir-Am, 2010:154).

Historical research on women in science, however, shows that “the masculine profile of the sciences, as they have developed in the Euro-American context in the last 300 years, was by no means monolithic or inevitable” (Crasnow et al., 2015). Schiebinger (1989:100) argues that the emerging sciences “st[ood] at a fork in the road” regarding the inclusion/exclusion of women. She argues that the path to exclusion was taken when the sciences became defined by monastic university traditions and aristocratic men's associations – that not only excluded women but ‘purged’ all things considered feminine (Crasnow et al., 2015).

Whilst women were formally excluded from scientific institutions, female scientists found various ways to participate in scientific activity. Until mid- and late-19th century scientific activity was often conducted from home and so female scientists often contributed to a scientific household (e.g. Caroline Herschel who discovered various comets) (Abir-Am and Outram, 1987/1989; Schiebinger, 1999). Women scientists found other ways to continue to practice science, for example by finding enlightened mentors, ‘limiting familial responsibilities’, creating single sex educational institutions, and concentrating in those scientific disciplines that were congruent with more traditional gender roles e.g. botany (Am-Amir, 2010:154).

Women's entry, pioneers, and female firsts

Women's participation in science, however restricted, did challenge bourgeois gendered stereotypes that confined many women to the private sphere, and supposedly ‘scientific’ arguments that questioned their ability and suitability for science (Abir-Am, 2010:154). This is why the work carried out by historians of women in science plays such an important role, making visible and celebrating women's

achievements, discoveries and contributions to science, often otherwise forgotten and marginalised (see, for example, Sayre (1975) for a discussion of Rosalind Franklin's career; Fox Keller's (1983) book on the life and work of Barbara McClintock; Rossiter (1982) *Women Scientists in America: Struggles and Strategies* to 1940; Schiebinger (1999, chapter 1) for a summary of historical heritage of women in science.)

"Universities have not been good institutions for women", summarises Londa Schiebinger in *Has feminism changed science?* (1999: 25). The first universities were founded in the twelfth century, and women were excluded from study until the late nineteenth century. There are a few early exceptions of women pursuing university studies, mainly in Italy, such as Elena Piscopia who earned as first woman in Europe a university degree in 1678 in the University of Padova, and the physicist Laura Bassi as the second woman in Europe in 1732: Bassi later became the first woman awarded a university professorship (see Schiebinger 1999: 25). Some women migrated specifically to obtain a university education, for example, in medicine, unavailable in their home country. In US, from the 1860s some universities and colleges began to admit women, thereby facilitating access to formal scientific training (Crasnow et al., 2015). For the next 60 years or so there was in US a great increase in the numbers of women working in a wide range of fields and institutions (Rositter, 1982: xviii). Women, however, tended to be confined to the positions of technicians, assistants or even providing 'human power' for the function of 'computer' work – for example, observing stars and counting (Rossiter, 1982; Schiebinger, 1999). Although the gains made by women were far from achieving parity in science, it was a significant, albeit fragile step forward.

History of feminism, feminist movements, and different conceptions of gender

Feminist research on gender and science has made a significant contribution in terms of analysis, and policy developments in this field. Hearn and Husu (2011) have used Lorber's (2005) terminology to highlight how different policy approaches can be linked to different feminist approaches: gender reform, gender resistance and gender rebellion feminisms in the field of gender and science, which in turn reflect different conceptions of gender. Indeed different ways of understanding sex/gender tend to inform such diverse political approaches, and vice versa.

Gender based on sex

In terms of the first conception, gender based on sex is prominent when looking at gendered individuals in science and technology (Hearn and Husu, 2011). Sex and sex differences have often been and are often still naturalised as based or fixed in biology, in binary attributions based on chromosomes; even though there are also major chromosomal variations beyond the main XX and XY types, with fifteen types of intersexuality. A sex-based approach is often used in relation to documentation of women's under-representation in science. A number of critical feminist biologists, such as Fausto-Sterling (2000), have developed sophisticated and grounded accounts of how biology itself does not neatly conform to a two-sex female/male model but is in fact much more variegated in many possible sexes among humans, and in other species.

Masculinity/ femininity and sex/ gender roles

The conceptual leap from sex (biological determinism) to gender (socio-cultural constructions of sex differences) has seen much work produced in this field; as such, it was part of a major contribution of Second Wave feminism in the 1960s and 1970s. This has included studies across the social sciences, for example, social psychology (Bandura, 1986; Bussey & Bandura, 1999). In terms of policy, a liberal reform feminist approach (Lorber, 2005) focusing on formal equality places emphasis on encouraging equal opportunities and equal representation between men and women. This approach characterises the broad raft of science and technology policies that attempt to increase the representation of women by targeting gender balance on key boards, top positions, etc. – without aiming fundamentally changing or questioning the structures and culture of science. Even though it enables some gains for some individual women in science, and can bring more diverse perspectives into decision-making, this approach has been subject to wide-ranging criticism – including its' absence of a recognition of power, its' binary notion of sex/gender, and a lack of analysis of the various structures that tend to reproduce gendered inequalities.

Gender categorialism, gender structures and structurally contextualized practices

A more socio-cultural perspective places emphasis on gender structures (patriarchy, fratricide, gender systems, gender orders, gender contracts) and structurally

contextualized practices (Hearn and Husu, 2011). This approach can be linked to 'standpoint theory' which highlights that "(1) Knowledge is socially situated. (2) Marginalized groups are socially situated in ways that make it more possible for them to be aware of things and ask questions than it is for the non-marginalized. (3) Research, particularly that focused on power relations, should begin with the lives of the marginalized."¹ During the late 1970s and early 1980s there was a shift to a more differentiated, plural approach to gender which was accompanied by a recognition of patriarchy as multiple structures (Walby 1990; Hearn, 1992). Such developments gave a more predominant place for men and masculinities to be explored and deconstructed in gender studies (Collinson & Hearn, 1994). Accordingly, Lorber's (2005) 'gender resistance feminism' calls for a more radical approach to policy and practice than one seeking gender balance – men's dominance is considered to be too strong, and change will not occur by merely increasing the representation of women, but the gendered social order needs to be fundamentally reshaped by including women's voices and abolishing patriarchy in science and technology (Hearn & Husu, 2011).

Within this broad feminist perspective, there has also been a major growth of scholarship on the connections and intersections of gender with other social divisions, within what has come to be known as intersectionality theory. This approach emphasises the intersections of gender and other social divisions (Crenshaw, 1989) and dates back at least to black feminism in the nineteenth century. It has built on perspectives such as critical race theory, and is in turn informed by and informing of global, postcolonial and transnational feminisms. Whilst gender studies is increasingly diverse, an intersectional approach is increasingly recognised as necessary.

Poststructuralist, discursive and deconstructive approaches

The notion of women as a homogenous group has also been challenged – bell hooks' book '*Ain't I a Woman?*' – published in 1981 charts the marginalization of black women within the feminist movement. The importance of recognizing multiple differences and feminisms came to the fore and an intersectional approach that takes gender into consideration alongside age, class, ethnicity and occupation was now seen as essential. Queer theory also heavily influenced third-wave feminism by

¹ <http://www.iep.utm.edu/fem-stan/>

challenging binary notions of 'male' and 'female'- whilst promoting a more nuanced understanding of bi-sexual and trans identities. This has led to such approaches to gender and science beyond the study of humans, as in queer biology, that considers fluidity and the non-binary, including difficulties of classifying individuals as either male or female, also in the natural world. Gender shifts from 'being' someone to 'doing' something as 'gendering' is performed (Butler, 1990). This umbrella of 'post' positions attempt to 'take apart the gendered social order by multiplying genders or doing away with them entirely' (Lorber, 2005: 12). Interactions, intersections and connections however with other social divisions and oppressions takes central stage – along with deconstructing “categories of sex, sexuality and gender, and the dualities (re) produced through them (see Lorber, 1994, 2000).” (Hearn and Husu, 2011). In terms of policy approaches to gender and science, we can see how the UK Athena Swan Charter has been redefined in this direction: “it was established in 2005 to encourage and recognise commitment to advancing the careers of women in STEM employment in higher education and research ...but in May 2015 the charter was expanded for trans staff and students. The charter now recognises work undertaken to address gender equality more broadly, and not just barriers to progression that affect women.”²

The shift from 'third' to 'fourth' wave feminism is currently subject to debate as some commentators chart how radical shifts to online communication practices marks a new era for feminism. Online tools are being used to chart and challenge sexism. Examples include the UK Everyday Sexism project that enables users to upload their stories of sexism online, and the twitter campaign in 2015 where women scientists posted their #distractingly sexy photos (i.e., photographs of themselves in lab coats) in response to comments made by eminent scientist and Nobelist Tim Hunt who had complained in public of “the trouble of girls” in laboratories³. The internet has also facilitated local, regional and global networking of feminists⁴ and email list serves⁵ in the field of gender and science – where interested parties can remain up-to-date in this field. A very inspiring intervention is the 'Congrats, you have an all male panel!',

2 <http://www.ecu.ac.uk/equality-charters/athena-swan/about-athena-swan/>

3 <http://www.theguardian.com/science/2015/jun/12/tim-hunt-trouble-with-girls-in-science-comment>

4 See <https://feministnetworkproject.wordpress.com>

5 EQ-UNI-European Network on Gender Equality in Higher Education (http://www.helsinki.fi/henkos/tasa-arvo/eq_uni.htm)

created by the Finnish political scientist Saara Särmä, inviting readers and contributors to highlight all-male panels in science and beyond.⁶

Others, however, are keen to point out that a shift in the tools of communication does not in itself constitute a paradigm shift (Munro, 2015). Whilst there is a growing body of research that is charting a reinvigorated feminism – linked to the use of ICTs, the internet and new socio-technologies – whether this activism can be linked to transformative political action is highly contested (ibid.).⁷

The material-discursive

Poststructuralist and materialist approaches to gender, science and technology have provided useful insights for radical new perspectives on this relationship. For example, much work carried out in Science and Technology Studies seeks to reposition human/nature (including matter) relationships by questioning the very binary nature of their separation. Humans become to be understood crucially as one part of social networks, and crucially objects are also seen to form part of these. Haraway (1992) speaks of material-semiotic actors, whilst Akrich and Latour (1992) human-non-human assemblies. This material-discursive approach contends that “gender and sex are not separable from bodily matter, and ‘matter’ itself is social and constructed, in part through human/non-human species interaction (cf. Haraway 1989, 2008)” (Hearn & Husu, 2011). Gender therefore becomes ‘complex, contested, material, bodily and discursive’ as well as deeply entwined with other divisions and discourses of oppression. The very notion itself of gender and science as a specific and separable policy area of intervention disappears (ibid.).

At the beginning of this article we noted three major ways in which gender and gender relations are relevant for science, technology and innovation: *who does science, technology and innovation? How are science, technology and innovation organized? And how is knowledge constructed in science, technology and innovation?* How these three ways connect to the five broad approaches to gender outlined are summarised in the table below (Hearn & Husu, 2011).

6 <http://allmalepanels.tumblr.com/>, <https://www.tumblr.com/search/all%20male%20panel>

7 Munro, E. (2015). Feminism: A Fourth Wave? Last accessed online 14th March 2016: <https://www.psa.ac.uk/insight-plus/feminism-fourth-wave>

	<i>Gender based on sex</i>	<i>M/f and sex roles</i>	<i>Gender structures and plural practices</i>	<i>Poststructuralism, discourse and deconstruction</i>	<i>Material-discursive</i>
<i>Gendered individuals in science, technology & innovation</i>	Strong emphasis	Strong emphasis	Medium emphasis	Medium emphasis	Medium emphasis
<i>Gendered organizing of science, technology & innovation</i>	Weak emphasis	Medium emphasis	Strong emphasis	Strong emphasis	Medium emphasis
<i>Gendered knowledge in science, technology & innovation</i>	Weak emphasis	Weak emphasis	Medium emphasis	Medium emphasis	Strong emphasis

While all approaches are relevant to all realms, the increasingly broadening and ambitious range of gender studies has raised increasingly complex and far-reaching questions, including the very nature of science and technology itself. When investigating gender and STI, whether in analytical, policy or indeed personal terms or agendas, it is necessary to stop and think: how do I understand gender, and what implications follow?

The concern with history and the past shows how the present day, contemporary situation of gender and STI cannot be understood out of context, out of time and place. Similarly, concern with the future is essential – to make sense of the current state of gender and STI, the directions in which this is changing, how change is resisted and made difficult, and moreover the directions of possible change in gender and STI, and how it should change.

Futures: Why attend to the futures of gender and Science, Technology and Innovation?

Trends in science, technology and innovation.

Whilst it could be argued that all policies are in some sense future-orientated, developments in the field of gender and STI signal a growing interest in the future of gender and science via forecasting and the re-imagining of futures. Future Studies is

an established discipline. This includes both relatively short-term studies, including those conducted by governments and policy organisations, and long-term studies (see, for example, <http://www.futuretimeline.net/>). Forecasting STEM skills shortages for the labour market is an increasingly important short-term driver in the field. These studies are conducted to provide an impetus for policy action down-stream – in order to make STEM studies more attractive to young people. In some instances, these specifically target girls and young women.

A more radical approach aims at cultural and institutional change through re-visioning by imagining a gender-neutral science for the future. The Austrian Federal Ministry of Science, Research and Economy (BWF) commissioned research to use creative methods to look at how “researchers, academics and other experts ... develop their visions of a gender-neutral landscape in science, academia and research in 2025. These visions were then used to identify relevant fields of action for initiating cultural change.” (Wroblewski et al., 2014). Re-imagining futures is a powerful way to effect change in this area.

Future studies and foresight activities that aim to envision more distant than immediate futures and alternative scenarios need to address and integrate gender approaches in their work in a more comprehensive way. Global advocacies for this kind of actions include GenderINSITE (<http://genderinsite.net/about/>), and the Millennium2025 Women & Innovation Foundation, (<http://www.millennia2015.org/page.asp?id=87>).

All major scientific and technological changes have implications for gender and gender relations. New technologies and technological change and advances all have implications for gender. Science and its development is strongly influenced by the modes of its organisation, including the globalisation of science, the current dominance of various rankings of institutions, journals and publications, and the increasing impacts of marketisation, capitalist restructuring, and the commodification of knowledge – each with their gendered implications and strong gendered critiques. Another key example here concerns gender in/and ICTs, AI, virtual realities, and robotics. For example, big data analysis, often using indirect and supposedly unobtrusive data collection methods, and the Internet of things are now both with us. Miles Davis (2008), the chair of a US research consultancy company specialised in semantic technologies, predicted in 2008 that Web 3.0 semantic technologies will represent and produce new meanings by connecting different knowledges, and this

will serve as a basis for Web 4.0 – the meeting of artificial or machine knowledge and ‘the human’, linking with what is sometimes referred to as the (technological) singularity: “a future period during which the pace of technological change is so rapid, its impacts so deep, that human life will be irreversibly transformed.” (Kurzweil, 2005: 7).

But there are many further technological developments and examples to note, some already here, some likely in the future. These include: increased technological innovations in relation to the environment, climate change, disasters, energy, and transport; human enhancement, including neurological enhancement; bio-monitoring and surveillance by governments and employers; foetal monitoring, the selection of sex, and the possibilities for designer babies; human cloning; the quantified self and bio-hacking social movement, in which people undertake intensive monitoring of their bodies and selves; sexually-coded ‘implants’ allowing people to seek others with similarly or compatibly coded preferences, interests or sexualities; the transformation of touch and other senses; and new approaches to ageing, such as the end of retirement. These all have profound gender aspects, in their form, dynamics and knowledge construction.

One further arena where the future of science from gender perspective has been explored and envisioned is feminist science fiction, from early pioneers such as Margaret Cavendish, Mary Shelley and Charlotte Perkins Gilman, to Marge Piercy, Ursula Le Guin, Joanna Russ, and Doris Lessing (for a summary, see “Dreaming the Future” by Rose, 1995: 208-229). Rose remarks how much of the modern feminist science fiction has its focus on reproduction, both human and global (p. 228). “More thinkable and sustainable futures are nurtured by these dreams and myths of other wor(l)ds [feminist science fiction]; and feminists, whether working inside or outside the laboratories, have need of the laboratory of dreams” (p. 229).

Trends in gender and gender relations

What are the future possibilities for gender, gender studies, and the study of gender relations, in relation to science, technology and innovation? There are many contemporary changes and innovative developments in the construction of gender and gender relations, and within gender studies and gender analyses more generally, for example, the co-production of gender/technology, the unsettling of gender beyond binaries, and transgender studies. This is indeed an exciting time for the study of

gender and science, and STI – as a “comparative and transnational nexus of interdisciplinary and post-colonial potentialities” (Leurs, 2009). Debates on gender and science, and its future relations, are no longer only about the numerical representation of women (as if that ever was the case) but concern a much broader canvas of methodology, epistemology and ontology in, of and around both gender and science, technology and innovation, seen in gendered global, transnational and postcolonial terms.

During the late 1980s a scholarly approach to gender and technology, namely, co-constructionism, was developed and continues to produce fruitful insights in this arena (Caprile et al., 2012). It challenged notions of gender essentialism, that men and women are inherently different, with subsequent implications for technological development, and technological determinism, that technological development shapes gender. Co-constructionism emphasises the mutually interdependent nature of their relationship – that gender relations shape technology just as technology shapes gender relations. Wajcman highlights how ‘gender relations can be thought of as materialized in technology, and gendered identities as produced simultaneously with technologies’ (Wajcman, 2007) (see also Caprile, 2012: 162). This approach recognises the intimately linked nature of people and artifacts, thus paving the way for a more fluid and interactive understanding of gender, technology and science. One area where such thinking is relatively well researched is in relation to men, masculinities and technology and technological disaster (for example, Amier and Messerschmidt, 1998), and to some extent in relation to medicine (for example, Rosenfeld and Faircloth, 2006). This issue needs much more detailed research studies. Although a co-constructionist approach to gender and science is increasingly recognised as a fruitful scholarly perspective in the field, there are also critiques of this approach, as well as questions in terms of what are the policy implications of this approach.

As noted in the introduction, limited notions of gender are often in use; science is not only about non-gendered men and boys, and gendered women and girls. Indeed there are many other possible genders and genderings than such binaries. Such thinking around gender pluralism (Monro, 2005) is now well developed. Many texts have shown the limitations of a view of gender as in a fixed relation to sex, and an overly dichotomised view of gender relations. These include historical and cross-cultural analyses of “multiple gender ideologies” (Meigs, 1990), “gender ambiguity” (Epstein & Straub, 1991), and “the third sex/third gender” (Herdt, 1994). Another set

of approaches derive from historical dialectical processes of transformation of men as a gender class (Hearn, 2004; Howson, 2006). A third derives from practices of undoing gender, queer theory, and transgender studies (Hearn, 2011: 27-28).

In considering the limitations of seeing gender as in a fixed relation to sex, and of an overly dichotomised view of gender relations, we take the developing field of transgender studies as one example of relevant scholarship. Enke (2013) in her book, *Transfeminist Perspectives in and beyond Transgender and Gender Studies*, highlights the productive yet 'sometime fraught potential' of the relationship between gender studies and transgender studies. Transgender studies may add to gender studies the notion that "gender and... sex are made through complex social and technical manipulations that naturalize some while abjecting others." (Enke, 2013: 1). She argues that transgender studies is powerful due to its three-way awareness:

- "binary gender norms and gender hierarchies are established and maintained through violence against those who visibly deviate from them;
- many humans in their gender identities and/ or gender expressions – do not conform to conventional gender expectations or moral judgements about what kind of gender "go with" what kind of body
- this gender variation is intensely valuable as one facet of the creative diversities essential to wide and flourishing societies." (Enke, 2013:6).

Each of these observations raise complications for a simple equation or simple relation of sex and gender, for both analysis and policy development, and in particular problematises a binary sex/gender approach to STI. This applies whether attention is directed at who does STI, how STI is organised, and the very form and content of knowledge within STI itself.

Conclusions

Looking back to the histories and herstories of gender and science helps us to gain a better understanding of the gendered roots and patterns of social and cultural inclusion and exclusion. This may begin to explain partially current issues of representation in science. Excavating into the past also challenges notions of historical determinism – thereby making space for and recognising alternative possible outcomes. Opening up possible futures in the field of gender and STI may

provide exciting opportunities to re-imagine gender-neutral or very differently gendered scientific landscapes. Linking different conceptions of gender to research perspectives and policy interventions in this field – in the past, present, and indeed expected and possible futures – may also help to unravel, unpick and subsequently develop more sophisticated and targeted approaches – to effect a greater transformation in STI and society more generally. Diverse histories, current and future trends, co-productions of gender and technology, and challenges to conceptions of gender itself all raise fundamental questions for STI: *who does science, technology and innovation? How are science, technology and innovation organized? How is knowledge constructed in science, technology and innovation?*

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Note: The present document gives a brief overview of recent research findings regarding *Historical Perspectives and Future Scenarios* in Gender and Science. Further research syntheses on (1) Education and Training, (2) Academic and Science Careers, (3) Institutional Practices and Processes, (4) Gender in Research Content and Knowledge Production, and (5) Policy Setting and Implementation are available at www.genderportal.eu

An **up to date version** of the bibliography and further relevant resources can be found at the following address:

<http://www.genderportal.eu/tags/research-synthesis-6-historical-perspectives-and-future-scenarios>



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