Innovative Women: Illuminating Achievement and Success

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Abstract

This paper aims to illuminate the achievement and contribution of women to high level scientific and technological advancement and entrepreneurship. This is undertaken through the presentation of self explanatory case studies of 'seven' successful past and present female scientists, engineers, industrial designers, and entrepreneurs from Europe and North America. The main focus of the paper is on the nature of success and achievement in terms of scientific discoveries, invention, innovation, commercialisation, and business venturing, whist at the same time providing unique insights into the work- life journey. The women included in this paper come from diverse backgrounds, they have all overcome being gender stereotyped to enter and succeed in a variety of traditionally male dominated sectors. They exhibit the breadth of women's innovative and entrepreneurial ideas, combined with a curiosity and ability to put words and thoughts into action. Although the paper acknowledges that women hold a minority status in certain scientific fields, it argues that 'gender imbalance headlines' captured in current statistics, media, policy and research undermine the contributions being made by women to technological advancement. The paper builds upon historical research that shows women have been behind a much larger number of innovations and inventions and patent than traditionally given credit for. The involvement of women in the invention, innovation, patents and registered design that took place between 1637 and 1914 has been uncovered and published by Deborah Jaffé in 2003 in her book, 'Ingenious Women'. However, there remains a gap in knowledge of women's contribution in these areas post 1914. The paper demonstrates that it is vital to track those women who in the last one hundred years, can be used as examples, not as idols, but as 'real women' to show their abilities to problem solve, make improvements and be innovators alongside their everyday lives.

Key words: Women; Innovation; Technological Advance; Patent; Entrepreneurship

Background

For centuries, scientific discoveries and technological innovation, have been acknowledged as being amongst the most crucial sources of economic growth, competitiveness and increased material and social welfare (Edquist, 2005; Sainsbury, 2007; Wynarczyk and Marlow, 2010). Intellectual Property Rights (IPRs) are increasingly seen as vital tools for commercialisation and exploitation of innovation and technological advances. Patent, in particular, is widely accepted as a key measure for the overall innovativeness of national economies in the global knowledge-based economy (Arundel and Patel, 2003; Kugele, 2010). Patents and registered designs are important tools for researchers of science, technology, engineering and design. They contain information about the patent holder, including, name, address, status, occupation, as well as the actual nature of the patent, drawings, types of materials used and methods of construction and manufacture (Jaffé, 2010). Moreover, the examination of patent applications and registered designs provide a unique opportunity to assess the contribution made by individuals to technological change, entrepreneurial activities, economic prosperity, personal accomplishments, society and public life as a whole.

Scientific discoveries and technological innovation are amongst the most significant achievements of the creative human mind and are gender neutral. Josef Schumpeter, for example, viewed science as tooled knowledge and loosely associated material transformations with intellectual transformation of individuals (Schumpeter 1934; Wynarczyk, et, al, 2000; Wynarczyk and Marlow, 2010). Elizabeth Boody Schumpeter (1954), in her book 'History of Economic Analysis', defined science *as 'any field of knowledge in which there are people, so called research workers or scientists or scholars, who engage in the task of improving upon the existing stock of facts and methods and who, in the process of doing so acquire a command of both that differentiate them from the 'layman and eventually also from the mere 'practitioner' (1954:7).* High level scientific activities of individuals in terms of, for example, research and development (R&D), innovation, invention and exploitation of IPR, are vital for economic prosperity and social welfare (Wynarczyk, 2007). The participation of individual researchers in patent applications, in particular, reflects the successful inventive achievement in science and technology and provide an incentive for internal and external investment in innovation and diffusion of technology (Arundel and Patel, 2003).

The overall purpose of this paper is to illuminate the achievements and contribution of women to high level scientific and technological advancement and entrepreneurship. This is carried out through the presentation of profiles of life and work journeys of 'seven' successful past and present female scientists, engineers, industrial designers, and entrepreneurs from Europe and North America. The main focus of the paper is on the nature of success and achievement in terms of scientific discoveries, invention, innovation, commercialisation, and business venturing, whist at the same time providing some unique insights into the work- life journey. More specifically, the paper aims to:

1. Illuminate and showcase the actual nature of these women's scientific research, innovation, invention, patents, and industrial design, which can result in 'atypical' entrepreneurial ventures in the public and private sectors.

2. Highlight some key challenges and obstacles these women faced and how they managed to find their own creative solutions to overcome them.

3. Demonstrate the subsequent impact and contribution made by these women to scientific and technological advancement, entrepreneurial activities, society and public life as a whole, as well as their personal accomplishments and achievements.

Existing research and policy tends to be based on publicly available annual data that focuses, mainly, on men and women in positions that have a potential (or lack) to produce technological advances, rather than their actual contributions to various facets of R&D and engagement in the processes of technological and scientific advancement. This has led to numerous research and reports focusing on the obstacles that contribute to the continuous dropout rates of women, i.e. the leaks in the stages of the so called 'STEM pipeline (the transition from education to careers related to the glass ceiling) in certain scientific fields (e.g., Cronin and Rodger, 1999; Greenfield, 1994, 2000; Blickenstaff, 2005; Watt, et al, 2006). Hence, undermining the contribution made by women to technological advancement and scientific discoveries throughout history. In contrast, there are few reports and studies based on the identification of success factors and discussion of issues by women scientists themselves who do persist, overcome challenges and succeed (Monosson, 2008; Wynarczyk and Marlow, 2010). Furthermore, the little research that has gone beyond comparing patent numbers and other related statistics between male and female, and focused on the actual involvement of women in the process of scientific discoveries, invention and innovation, has unravelled the pivotal role that women have played in these fields (Hamilton, 2000; Fara, 2004; Jaffé, 2003, 2010). Focussing on obstacles provides little support to those employed, or planning to enter these professions. On the contrary, this can be a self-fulfilling prophecy, and have an adverse effect, and as such, may actually discourage girls and women from pursuing education and careers in these fields. If these women are invisible and unrecognised for their contribution to scientific and technological advancement and not seen to be enjoying rewarding, successful and progressive careers, they are unlikely to be able to act as role models and serve the purpose of further recruitment and retention (Wynarczyk, 2006). This paper aims to address the gap in the knowledge in this area.

Innovative Women: Lack of Participation or Invisibility

On the surface, there does not appear to be any fundamental reasons why women should not equally participate in the inventive, innovative processes, patent, and R&D activities that result essentially from 'brain work'. Prior to the 20th century women were believed to have been denied and prevented from equal participation in scientific fields for several reasons, including, the construction and perception of gender role in society, lack of access to education and employment that resulted in financial dependencies on fathers, brothers or husbands (Hamilton, 2000). During the 19th century, for example, women had to struggle and challenge to be admitted to medical schools or study mathematics (Jaffé, 2003). The suffrage movement in various countries changed women's lives. It resulted in, for example, the Representation of the People Act passed in the UK in 1918, giving women over 30 the right to vote, followed by subsequent legislations, including the Equal Pay Act of 1970, the Discrimination Act 1975, and the Gender Equality Duty (GED), 2007. Today, women should be in a far better position to participate to the scientific and technological advancement at the same level as their male counterparts.

However, despite some slight improvement in the level of participation by women in these fields, the legislation, positive action measures and public policy have been largely ineffective and this crucial division of education, labour market, and scientific activities, in general, remains male-dominated. A recent report produced by GHK (2008) suggests that within the Member States of the European Union, on average, only 8.3 per cent of patents awarded by the European Patent Office are owned by women and only 5 to 15 per cent of high-technology-based businesses are established by women. In the UK, only 5.3 per cent (about one in twenty, of all working women) are employed in science, engineering and technology (SET) occupations, compared to 31.3 per cent for all working men (nearly one in three). Furthermore, existing research suggests that the majority of university spinouts (e.g., licensing, company spin offs are generated from innovations and inventions in the areas of SET that are historically, largely, male-dominated fields. As fewer women participate at the 'cutting edge' of SET or hold senior position in the scientific departments, they are unlikely to be the founders of spinout companies.(Rosa and Dawson, 2006). It has been argued that as a result of equal opportunities legislations and laws in education and employment, formal discrimination against women has, at least in theory, been removed (Wynarczyk, 2006). However, there are several professional, institutional and personal barriers that continue to prevent equality for women in these fields, including, the institutional sexism, stereotyping, societal attitudes and assumptions both by and towards women in science, technology and entrepreneurship and the deeply rooted culture of the scientific enquires (see Wynarczyk and Marlow, 2010 for an overview). As Jacob Clark Blickenstaff (2005) correctly points out, *'no one in a position of power along the pipeline has consciously decided to filter women out of the STEM stream, but the cumulative effect of many separate but related factors results in the sex imbalance in STEM that is observed today* ' (p. 1).

Moreover, Wajcman (2009) argues that the persistent under-representation of women in engineering, and other scientific and technical institutions, is a 'legacy' of the way in which technology has, historically, been defined as *'masculine, and masculinity is identified with technical competence'.* There is a close attachment to conventional and traditional thought and behaviour, to sticking with the known, and being unwilling to 'break out of the box' of traditional patterns, culture, stereotyping and routines. As Schumpeter (1934: 84) stated *'all knowledge and habit once acquired becomes as firmly rooted in ourselves as a railway embankment in the earth'.* We find it difficult to adopt new practices, methods, or views.

Although it is widely acknowledged that women hold a minority status in certain scientific fields, 'gender imbalance headlines' captured in current statistics, media, policy and research undermine the contributions being made by women to technological advancement (Wynarczyk and Marlow, 2010). In fact, historical research shows that women have been behind a much larger number of innovations and inventions and patent than traditionally given credit for (Hamilton, 2000; Fara, 2004; Jaffé, 2003, 2010). According to Jaffé (2003), there is a hidden history of 'ingenious women' going back nearly 600 years starting with the first English patent granted to a woman in 1637. The original research carried out by Jaffé (2003) that included, a sample of English, British, and US patents by women in Europe and North America, revealed over 500 female patent holders between that first patent (1637) and the outbreak of World War I in 1914. Initially, the appearance of women's names in the historical lists and registers of patents is sparse, increasing annually through the 19th century. After the 1852 Patent Act (Britain) was introduced, following the success of the Great Exhibition 1851, the numbers of women patent holders rose to a high of 2% in 1898 when There were 638 patent applications by women out of a total of 27,639 (Van Dulken, 1999).

One the main reasons for the 'invisibility' surrounding women as innovators and inventors stems from the lack of academic evidence surrounding their contribution which is further worsen by the exclusion of gender indicators within government surveys. As already been referred to, the involvement of women in the invention, innovation, patents and registered design that took place between 1637 and 1914 has been uncovered by Deborah Jaffé and published in 2003 in her book, 'Ingenious Women'. However, there remains a gap in knowledge of women's contribution in these areas post 1914. It is vital to track those women who in the last one hundred years, can be used as examples, not as idols, but as 'real women' to show their abilities to problem solve, make improvements and be innovators alongside their everyday lives (Fara, 2004; Jaffé, 2010).

Methodology

Technological advancement of knowledge-based economies are generally measured by two key indicators, the quantity of patents and R&D intensity. Research, policy and practice generally tend to focus on STEM occupations and the roles performed by women and contribution made within these occupations are left largely to conjecture. There is a particular scarcity of data and research on the parts women play in the scientific fields outside the university departments. Furthermore, the degree to which women occupy positions that are directly connected to scientific activities and discoveries remains largely unknown. Consequently, women do not appear strongly in the inventive and innovative literatures except as exceptional historical examples and idols (e.g. Marie Curie) rather than as a result of a well researched topic. This is, partly, due to the implicit assumption that invention and innovation are largely the preserves of men perhaps reflecting the engineer-driven (masculine) designs of manufacturing and male dominance of particular industries and occupations. Women's contributions to technological advancement remains unmeasured and it continues to be difficult for their work in these fields to be taken seriously.

This paper, uses a case study approach to unravel the level of determination, talent, strategic planning, creativity, and ingenuity that women scientists, engineers and industrial designers have demonstrated and experienced to achieve success and overcome obstacles and challenges. These cases offer excellent examples of role models and challenge the assumption and belief that women, in general, cannot be inventors, innovators and successful entrepreneurs within these fields and if they do succeed the outcome is of trivial innovative and insignificant commercial value or they are not 'real women'.

Case study research is appropriate within qualitative investigations when the interpretation of data essentially draws upon personal experiences and narratives, as well as the evidence that have shaped the individuals' lives. More specifically, the choice of case study as a research strategy within the social science discipline is believed to be highly appropriate when 'how' and 'why' questions are central to the research investigation (Yin, 1994). Furthermore, case studies assist us to understand women's activities, actions and experiences within different cultural and socio-economic contexts. The case study approach presented in his paper builds upon Haynes (2006) and more recently Wynarczyk and Marlow (2010) arguments that such case study approach is particularly appropriate method to inform research focused upon women's life and work journeys where key factors of social, economic and political activities are gleaned.

About the Case Studies

The purpose of the self-explanatory case studies presented in this paper is to construct detailed and rich descriptions of the ways in which women, who are assumed to be under-represented throughout history from certain areas of activities [innovation, invention, industrial design, and patent], have navigated through traditionally embedded social, cultural, and economic norms to claim a place within a space from which they are largely invisible, hence, being denied the recognition they deserve for their accomplishments. The case studies selected for this paper cover a broad range of individual achievements and entrepreneurship, as well as, for some, educational and academic opportunities. Annex (1) lists the women with relevant dates and professions. Their life journeys and achievements are presented in the self explanatory case studies in Annex (2). The women included in this paper come from diverse cultural and educational backgrounds, they have all overcome being gender stereotyped to enter and succeed in a variety of traditionally male dominated sectors. They exhibit the breadth of women's innovative and entrepreneurial ideas, combined with a curiosity and ability to put words and thoughts into action.

Annex 1
List of Case Studies

1. Hertha Ayrton (Née Sarah Marks)
1854-1923
Occupation: Mathematician and Electrical Engineer

2. Beatrice Shilling
1909-1990
Occupation: Aeronautical Engineer
Country: UK

3.Stephanie Kwolek
1923-
Occupation: Research Chemist
Country: USA

4.Gaby Schreiber (née Wolf)
1916-1991
Occupation: Industrial Designer and Entrepreneur
Country: UK

5.Ruth Handler
1916-2002
Occupation: Inventor and Entrepreneur
Country: USA

6.Eija Pessinen
1956-
Occupation: Midwife, Inventor and Entrepreneur
Country: Finland

7.Sudipta Roy
1963-
Occupation: Professor a, Inventor and Academic Entrepreneur

Country: UK

Annex 2

Case studies

1. Hertha Ayrton (Née Sarah Marks)

1854-1923

Mathematician and Electrical Engineer

Hertha Marks was born in 1854 to parents who were not wealthy but did recognise that they had an intelligent daughter. Fortunately, relations were able to fund a private education for Hertha, at a time when education for girls was still not on a par with that of boys. At school she excelled in mathematics and in 1876 she was amongst the first intake of students at Girton College, then a new college in Cambridge for women. According to Evelyn Sharp, Hertha Ayrton's biographer, she part financed herself by doing traditional female crafts of embroidery and tapestry for the socialist designer, William Morris. (Sharp, 1926). A concentration on, and fascination with, mathematics led to Hertha Marks inventing a line divider that was a rule that divided a line into equal lengths, which, in 1884, was patented in Hertha Marks' name as 'Improvements in Mathematical Dividing Instruments'(Patent GB5443/1884).

According to a review in 'Nature' magazine, in 1885, this was - '.. a very handy instrument for architects, engineers and practical drawing..'. It was manufactured by Mr. Stanley of Great Turnstile, Holborn, who was a specialist maker of scientific instruments. So great was its success that it was suggested to Hertha Marks that she become an entrepreneur and start her own business as an inventor and manufacturer of mathematical instruments. Like many academic scientists today, Hertha Marks had to make important career decisions and opted to be a researcher concentrating on the study of electricity, with Professor William Ayrton, who she married. Hertha Ayrton's definitive work, 'The Electric Arc' was published in 1902 (Ayrton, 1902), followed by numerous research articles in 'The Electrician'. She lectured at the Institution of Electrical Engineers and was the first woman to be elected a Member in 1899, the next one would not be until 1958. Attempts by the Royal Society to elect her as a Fellow were thwarted when their legal advice stated that it would be inappropriate to elect a married woman to their fold. Instead, her paper was delivered to the Society by John Perry and the first female Fellows were not admitted until 1945. The work on the electric arc eventually led to her patent for 'Improvements in or Relating to Lanterns or Enclosures for Lamps Used for Projecting a Beam of Light' in 1913, (Patent GB17865/1913), which were developed into searchlights and used by the Admiralty to detect enemy aircraft in World War I. However, in 1901, during the course of the research, Hertha Ayrton discovered it would have further implications. William Ayrton was convalescing in Margate and whilst relaxing on the beach there, she noticed that sand ripples form in equal patterns and applied this to her work on currents and vortices in water. she deduced that air could be repulsed, uniformly, by vortices. Years later, when the reports of poison gas in the trenches of the Western Front in World War I appeared, she found a practical application for her discovery and devised a fan or flapper on a portable parapet, which when beaten in a specific way set the vortices in motion to disperse the noxious gases. It was a simple solution to a potentially lethal problem and was patented in 1915 and again, with improvements in 1920 (Patent GB152828/1920). Evelyn Sharp notes that the War Office was dismissive of the simplicity of this solution and also because it had been devised by a woman. However, towards the end of the war they did purchase 100,000.

Not only was Hertha Ayrton a pioneering electrical engineer, she was also much involved with socialist politics, feminism and trying to change legislation where if affected women. She gave lecturers to women's groups on the uses of the 'new' electricity in the domestic situation, and when she was permitted, academic papers to professional groups. When her husband died in 1908 she continued her work, now moving her laboratory downstairs to the sitting room of the home in Rutland Gate near Hyde Park in London.

By the time she died, in 1923, Hertha Ayrton had proved that women can be research scientists of the highest standard, register the IP of their inventions, put their findings to important practical uses, have a lively social and family life and be at the forefront of feminist politics. Her obituary was published in the Times and there is now a blue, commemorative plaque on her home in Rutland Gate (The Times, 1923).

2. Beatrice Shilling

1909-1990

Aeronautical Engineer

Beatrice Shilling was a qualified engineer who loved speed and became a specialist in aeronautical engineering. Almost from birth she defied gender stereotyping by playing with the new construction toy, Meccano. Ironically, when Frank Hornby launched Meccano in

1901 he firmly believed that all boys should learn about mechanics and engineering by playing with it. Beatrice was also given a 2-stroke Royal Enfield motorcycle when she was fourteen. (Freudenberg, 2003).

In 1926, she became an apprentice electrical engineer in southwest England as electricity supplies for domestic use were being installed. Here she learnt how to wire a house and connect it to the main electricity supply and eventually became an area manager. This experience enabled her to complete undergraduate studies in electrical engineering at Victoria University of Manchester when, despite the advances made by Hertha Ayrton and other women a generation before, it was still unusual for women to be students on such courses. After graduating with an MSc, in mechanical engineering in 1933, she worked at the electrical engineering company, Ferranti in Hollinwood near Oldham. Often to the astonishment of her workmates, not only did she arrive on her motorcycle but also, on occasion, rode it into the factory building. In 1936, she moved to Farnborough and the Royal Aircraft Establishment (RAE). Brooklands racing circuit is close by and here she further indulged her motorcycling passion and broke many track records. Photographs of Beatrice Shilling at this time, taken on the track at Brooklands, reveal a highly confident woman, again defying gender stereotyping and sitting astride a Norton motorcycle, wearing leather boots, jacket and trousers topped by a helmet. Sometimes she modified her motorcycle to make it give extra speed, and became the fastest woman on two wheels when she was awarded the Gold Star for achieving 106 mph on the track. No doubt her engineering knowledge gave her practical experience in her leisure time activities that she would need in her work at RAE and eventual specialism in aircraft carburetors.

During the 1930s, the development of aeroplane engines was being constantly refined as war with Germany seemed inevitable. R.J Mitchell designed the Spitfire as a fast, short-range, fighter plane and it quickly became a crucial part of the RAF fleet during World War II. It had to match the German Luftwaffe's, well-engineered Messerschmitt and initially, it competed well. However, as the war progressed and longer sorties were necessary beyond the plane's original capabilities, problems arose which affected the fuel supply in the Rolls Royce Merlin engines of the Spitfire Marks I and II. Fuel would cut out when the planes nose-dived, a manoeuvre which was especially important for targeting on bombing missions. To regain full supply RAF pilots had to roll their aircraft over whilst the Luftwaffe, in the superior Messerschmitt, had no such problems. This was a time consuming and dangerous operation in which the lives of many RAF pilots were lost.

In 1941, Beatrice Shilling, now an experienced aeronautical engineer at the RAE and also a Brooklands motorcycle racing champion, combined her engineering knowledge and experience and invented a valve that resolved the potentially lethal problem on the Spitfire. This valve enabled the fuel to flow continuously no matter what position the plane was in. It consisted of a circular hole roughly 1.5 cm in diameter cut out of the centre of a brass diaphragm that was put across the carburettor. With this valve in place the pilots were able to steer Spitfires without loss of fuel supply (Glancey, 2006). Beatrice Shilling patented the valves as 'Improvements in or relating to carburetors' in 1946 with William Clothier. The valve became known, by the men of the RAF, as 'Mrs. Shilling's Orifice' (Patent GB 577099/1946)

3. Stephanie Kwolek

1923-

Research Chemist

Increasingly, during the last 100 years, women have been involved in the R&D teams in the chemical, pharmaceutical and engineering industries. For confidentially reasons, the work and identities of the individuals within the teams remain anonymous. However, it would be useful to discover more of women's roles and input, in the innovations, discoveries and eventual outcomes. Occasionally, some names do emerge from the laboratory to be embraced by a wider public and the names of others are recorded on patent and other IP documentation. Stephanie Kwolek is one such woman. Her work in the second part of the 20^{th} century, as a research chemist at DuPont in the USA, has had a profound effect on personal safety for people working on the front line of conflict, defence and disaster relief around the world.

Kwolek graduated with a degree in chemistry from Carnegie Melon University and, in 1946, joined a research team at DuPont which was at the forefront of the development of new polymers and plastic materials. In the 1940s and 50s, the full potential of these materials, especially plastics, was still being explored and few could have anticipated their profound effects on all aspects of life (Dupont, 2011). According to an interview with Kowlek in the New York Times in 1999, when she first went to work at DuPont, many of the developments in plastics were aimed at women as consumers – like Nylon stockings, Tupperware plastic boxes and kitchen work surfaces. Few in the company acknowledged women's potential as important research chemists - even if they were university-educated scientists. (Riordan T 1999) Quietly and by example, Kwolek would eventually change all that.

Stephanie Kwolek researched the uses of polymers and low temperature condensation processes to develop new fibres. She discovered that polymers with rigid, rod like molecules were difficult to dissolve but eventually, she did succeed. However, it was a thin and cloudy solution that emerged, and not what she was expecting. She was not disconcerted and took her experiment further to discover that these rod like molecules rearranged themselves into bundles, and each bundle was parallel to the next, so that all the rods went in the same direction. This uniformity made the resulting fibre very strong and stiff. On discovering this Stephanie Kwolek knew she had found something very important and patented her invention in 1963 as 'Fluorine Containing Aromatic Polycarbonamides' as a 'novel and useful class of polycarbonamides'. She describes her invention as '..an object ..to provide an aromatic polyamide having a melting point above about 350°C and sufficient solubility in organic solvents to permit spinning of fibres and forming of films therefrom. Another object is to provide a high melting aromatic polyamide which may be draw-oriented at relatively low temperatures.' (Patent US3328352; 1963). So, from the beginning the fibres were able to withstand great extremes of heat and cold.

Interestingly, she did not set out to invent anything but to find a fibre strong enough to reinforce car tyres. In 1965 her groundbreaking research led to the development of aramid fibres, which are very strong, fireproof, yet lightweight, which importantly created a bulletproof fabric. The fabric was patented and trademarked as Kevlar and its qualities make it ideal for stab proof vests and body armour used by police and the armed forces. It has been refined and styled to fit different sizes and tailored for men and women, and continues to be widely used around the world. There are now other uses for it including in fire-fighters' boots, bulletproof helmets, fibre optic cables, car braking systems and the manufacture of skis. Whilst her original research into a fabric to reinforce tyres was not overlooked and Kevlar has also been used in space vehicles and for landings on Mars.

During her career, Stephanie Kwolek was involved in 28 patents for Dupont, some as the outright inventor and many as part of a research team. She is a modest woman who regards herself not as a 'flag-waving feminist ' but as someone intent on breaking down barriers quietly, from the inside and in 1999 described her days at Dupont:

'If you were ambitious and applied yourself, you could acquire a great deal of knowledge. There were a lot of bright, creative men. This made the atmosphere in which I worked so stimulating and enjoyable.' (Riordan, 1999)

Stephaine Kwolek has, by example, shown a large company like Dupont that women are not only consumers of plastics in a domestic arena but can also be invaluable research scientists and inventors whose work has repercussions way beyond the home. The use of novel materials in clothing and the fashion industries has been profound in the last sixty years and women as well as men have been involved in their development.

4. Gaby Schreiber (née Wolf)

1916-1991

Industrial Designer and Entrepreneur

Industrial design is a relatively recent discipline arising from a combination of the great engineering advances of the late 19th century, the evolution of craft based activities into mass production along with the developments in new materials especially plastics and synthetics of the 20th century. As Jill Seddon has noted, since the late 19th century, the majority of women in all aspects of design have been sidelined by their male contemporaries even when they have graduated from design courses (Seddon J 2000). There continues to be an assumption that women are usually interested in craft based activities or that if they are involved in design it will be for fashion, or as Stephanie Kwolek discovered at Dupont, that women would only be interested in being the recipients of, in her case plastic items.

Born in Vienna, in 1916, she arrived in London in 1938 having trained as a designer in Austria and Italy she was influenced by European Modernism and the Bauhaus with their emphasis on industrial, mass production of well-designed objects for everyday use (Gropius W, 1935). Her designs utilised the streamlined qualities that plastics offer and even today her designs from the late 1940s for tableware appear very modern. All could be mass manufactured by her husband's company, Runcolite, and were cheap for the consumer. By the 1950s her clients included Midwinter Ceramics for whom she designed a range of iconic melamine tableware.

Schreiber's diaries reveal a hectic and exciting life of meetings with prospective contacts and clients; drinks and dinner parties; and visits to theatres and hairdresser. Again, this is someone who defied gender stereotyping, this time of women in the post war decades as 'housewives'; their dissatisfaction well described by feminist writers like Betty Freidan (Friedan, 1963). Gaby Schreiber married twice, did not have children and was a professional 'career' woman whose work was clearly integral to her personality. In 1948 Schreiber embarked on a four week, business trip to New York where she mixed with the top of the city's design world and witnessed the possibilities for plastics and Modernism. There were meetings with the Formica Company, the Industrial Design Society and New Design. In the same year she designed and patented a plastic cruet, the imagery of which, is clearly influenced by her trip and the materials reflect the very latest trend to introduce plastics to the table (Patent US 156283; 1949). This was patented in the US and UK, made of plastic by Runcolite, with the salt, pepper and mustard pots standing on a tray, in shape not dissimilar to the deck of an ocean liner. Each of the pots is angular in shape and decoration, taller than they are wide with flat tops and lids resembling the skyscraper cityscape of Manhattan.

By the time of the Festival of Britain in 1951, Gaby Schreiber was established as an industrial designer and entrepreneur with her own companies Gaby Schreiber Associates and Convel Designers Ltd based in Chelsea, London. In 1956 she attended the Women of the Year lunch at the Savoy Hotel and sat on of the Council of Industrial Design and Society of Industrial Artists and Designers. By now leading companies were drawing on her design services including Marks and Spencer, James Beattie Department Store in Wolverhampton, David Morgan of Cardiff and Fine Fare in Crawley. She redesigned millinery, ladies and menswear, hairdressing, food and delicatessen departments as well as in-store restaurants and coffee bars. In 1957 she was the colour and interior design consultant for the New Research Building of Thomas Hedley (P&G) at Longbenton near Newcastle upon Tyne. Where Beatrice Shilling improved the mechanics of the fighter aircraft, Gaby Schreiber became a leading designer for the interiors of the new, post war commercial aircraft, including the long-range jets like the VC10 operated by BOAC. To travel on these airlines, in the new jet age was a luxury afforded to the few and the experience had to match expectations. Gaby Schreiber, worked in all male teams of engineers, architects and furniture designers to produce interiors. She designed tableware and trays and her earlier galley kitchens and streamlined bathrooms were refined and transformed these interiors into places of futuristic, jet travel. Her influence can still be seen in the compact kitchens and the compact toilets in aircraft. Plastics were ideal, being light in weight, with pre-moulded component parts and easy to clean surfaces. Fabrics were selected to incorporate the airlines' colours and livery. Communication between the airline manufacturer and operator, engineers and designers was essential and regard for the comfort of passengers was vital to gain the competitive edge (Nash, 1960). In an article, for FLIGHT magazine in 1961 Gaby Schreiber wrote:

'*....The designer of the interior is expected to create an atmosphere which is not only attractive to the traveller…but which keeps him contented during the flight. A feeling of security must be induced, together with one of apparent spaciousness or freedom of movement. Nothing is more depressing .. than the sense of confinement.* ' (Schreiber, 1961).

Interiors for the Cunard's new Queen Elizabeth II in 1969, hotels and banks followed. By the time Gaby Schreiber died in 1991 she had risen to the top of her profession and was at the forefront of developments in the new synthetic materials and their incorporation into industrial design. She may be little known but her impact has been enormous.

5. Ruth Handler

1916-2002

Inventor and Entrepreneur

One woman's creation, first marketed in 1959, has come to dominate the world. Ruth Hander's Barbie, more than any other object, polarizes opinion on gender issues and imagery within children's toys but they are to be put aside here. The focus is on Ruth Handler, the inventor and entrepreneur who developed a global business, became its president, left and founded another company.

The evocation of a doll as an elegant, early pubescent female has existed since antiquity. The Egyptians crafted paddle dolls from wood and painted them to look like young women rather than children (Jaffé, 2006). The impact of plastics and new production technologies, after World War II, dramatically changed the design and manufacture of toys and dolls (Jaffé, 2006). In the late 1940s Ruth and Elliot Handler had a small business making modern, acrylic and plexiglas furniture and jewellery, in California. It quickly became profitable and they formed a company, which they named Mattel, to make wooden and plastic picture frames. Ruth was very successful running the marketing side and they expanded into making dolls' house furniture and other toys. By 1959 the Handlers' daughter, Barbara, was reaching puberty and her mother wanted a doll for her with a body that would reflect this stage in her life. So, much against the wishes of her male colleagues, Ruth Handler devised an 11 1/2-

inch doll that she called Barbie, after Barbara. The doll had highly stylized, large breasts and a proportionally, small waist body, its legs could bend without visible joints and was injection moulded from plastic (Jaffé D 2006 p142) Ruth Handler only envisaged it as a doll for teenage girls: In 1977 she said:

'Every little girl needed a doll through which to project herself into her dream of her future. If she was going to do role playing of what she would be like when she was 16 or 17, it was a little stupid to play with a doll that had a flat chest. So I gave her beautiful breasts.' (New York Times, 2002).

Handler was adept at getting the right materials scientists, engineers and designers to work on the product. Jack Ryan, a Californian engineer experienced in working with plastics, was commissioned to design the doll. Consequently, the patents for the Barbie doll, at this time, are usually in Ryan's name, and not Ruth Handler's. The patent drawings illustrate the detailed research in the engineering and design. Metal rods within the legs made them bend without the joints showing, waists swiveled and the soles of the tiny feet were shaped to enable them to stand in stiletto-heeled shoes.

The doll's success meant that seeing a new and lucrative market, other manufacturers on both sides of the Atlantic, veered away from their traditional 'babies and toddlers' and tried to emulate Barbie. These included 'Sindy' and 'Tressie". But, with boyfriend Ken who arrived in 1965, named after the Handlers' son, and numerous ranges of clothing, accessories, the Barbie brand went from success to success. In addition it was played with by ever-younger children so increasing the sales. Over the years, Barbie's shape has been refined and new plastics introduced into her production, but she is still, ostensibly the same Barbie as the one created by Ruth Handler over 50 years ago and is now a global brand with a name in the vernacular of popular culture (Jaffe, 2006).

The Mattel Company diversified, adding more toys to its range and employing 18,000 people worldwide. However, the Handlers left the company in the 1970s, Ruth having been its President. Ruth then developed and survived breast cancer but this did not deter her from starting another company. Nearly Me began business in 1976 when Handler could not find a suitable prosthetic breast for herself. At this time mastectomy was rarely spoken about in public and most prostheses were uncomfortable to wear and bore little resemblance to the form of a real breast. Using her knowledge of engineering and design in plastics, from the Barbie years, Handler transformed the concept of the prosthetic breast from being a 'medical appliance' to something resembling the real breast. As is noted on the company website, she used silicone and foam to '..fit the physical as well as the emotional needs of the mastectomies.' and is known as the inventor of the prosthesis that ' ..specifically fit(ted) the right or left side of the body, came in familiar bra sizes and followed the natural slope of the actual breast.' (American National Biography). She continued as director of Nearly Me Mastectomy Products until she sold the company to Spenco Medical Corporation in 1991.

Nearly forty years after Handler's launch into the prosthetic breast market she still appears on the Nearly Me company website and Barbie, now aged 52 has seen off numerous competitors and has become something of a style icon. Ruth Handler can be credited with being an astute businesswoman, an entrepreneur who twice realised a gap in the market.

6. Eija Pessinen

1956-

Midwife, Inventor, and Entrepreneur

From Midwife to the Founder and Chief Executive of the Born Global company, Relaxbirth Ltd. with a (R)Evolutionary New Birthing Philosophy, the Relaxbirth® System (method, birthing support -device, training and services). The Overall Award Winner of European Union Women Inventor & Innovator of the Year 2009.

A Journey into the Life and Work of Eija Pessinen

"Because I am a problem solver I enjoy challenges enormously. By nature, I like to develop ideas and put those ideas into practice. I have often found myself in situations in life and at work where I question myself if something could be done differently – or more easily. My dream was an empowering birthing experience for mothers and children to be born." Eija Pessinen recalls.

Specialist Nurse (SRN) Eija Pessinen was born in 1956 in a small northern forest village in Finland. She worked for many years in Finland, Germany and Switzerland before specialising into midwifery. As a midwife she was also a development worker in one of the poorest countries in Central America. That time Nicaragua had ongoing war and due to trade boycott it had general supply shortages, including petrol, medicines, disinfectants and instruments. There were also frequent power cuts which made gynaecological sample taking quite challenging. As part of her work as a midwife and healthcare worker in the city of Matagalpa, she also advised and trained local empiric, self learned midwives. She recalls, *”While teaching them, I realised how much I learned from them. It was truly wonderful to see how these midwives dealt with the process of delivery, even though they had no formal medical training nor equipment. Despite the challenging circumstances, they were able to successfully carry out natural home deliveries. This gave me even more confidence to trust on my own skills; what I felt in my hands, heard by my ears and saw with my eyes”... “Later after returning back to Finland, my sports hobby taught me how to use the body’s natural forces in an optimal way. This is not always obvious when people see the end-result, the Relaxbirth® birthing support, device.*

Eija also managed to complete two business degrees alongside her everyday work. *“My language skills gradually led me into more business-related tasks. That again, gave me oversight on how customer-friendly products and services should be, especially in the health sector.”*

Nursing and sales experience in Switzerland and Germany, Estonia and Russia, plus the years of studies alongside her work as a midwife equipped her with the skills and courage to develop new ideas. This ability was needed to gain self-confidence to further exploit her invention. She noticed that, *”the strength of the woman in labour decreased when she was pushing in an ineffective way, upwards (because of her anatomy) on the bed. It’s also waste of energy and utterly exhausting both for the woman and the child to be born.’*

In Finland it is the midwife who takes care of the whole delivery without the help from doctors, who will be called only if necessary so they, rarely, see normal delivery. In the summer 2003, Eija returned back to work in the delivery room. She observed midwives working in challenging, forward bending and twisted postures, sometimes even on the floor level. She thought *‘there must be a better solution than that’*. She decided to improve the situation after hearing some midwives were on sick leaves for several months because of musculo-skeletal back, shoulder, arm or limb pains. While working in business, she continued developing her invention and the first prototypes. Her endeavour and ingenuity led to the invention of Relaxbirth®, a groundbreaking system that represents a significant advance in the field of childbirth. Eija was awarded, for her invention, the European Union

Women Inventor & Innovator of the Year 2009. Today, Relaxbirth® is widely protected, rights are owned by Relaxbirth Ltd. whose HQ is in Finland, Europe. Eija is a major owner of Relaxbirth Ltd. Main partners are also board members who take active part in monitoring and managerial strategic decisions. In addition there is an International Advisory Board whose members are from around the globe.

About the Innovation

Relaxbirth® is a revolutionary system for childbirth which increases the well-being of the mother and child as well as the personnel in charge of the delivery. The system consists of the method, birthing support -device, training and services. The Relaxbirth® birthing support has been designed to provide midwives and doctors with an adjustable workstation offering improved working postures. It enables mothers during the whole duration of labour to relax their bodies and naturally find the most effective pushing position. The Relaxbirth® method contains know-how and training services on how to make giving birth a more relaxed and ergonomic, individually adjustable process for the mother-to-be. The method combines the psychological, ergonomic, physiological and practical know-how (www.relaxbirth.com).

7. Sudipta Roy

1963-

University Professor, Inventor, and Academic Entrepreneur

Sudipta Roy was born in New Delhi, India, in April 1963 to parents, originally from Bangladesh (originally called East Pakistan) who emigrated to Delhi from eastern India. Her father was an economist, her mother a housewife. She was the second of three sisters, all of whom were expected to follow their mother, to marry and become good housewives. She attended a girl's school, where three languages, Bengali, Hindi and English were taught. Her passion for science begun at school. Science gave her answers to some fascinating yet simple questions. Her early achievement was that of winning a national science talent scholarship, enabling her to attend science camps, where she was taught by scientists from National Physical and Chemical laboratories. Her O-levels followed 2 years later, she managed to get the highest marks in sciences out of 65,000 students. That was considered by her as 'the gateway' to study at a prestigious school, Delhi Public School, which was unaffordable for her family. She managed to make a personal appointment with the principal, to asked him for a scholarship, and succeeded.

Her father was unhappy with her decision to do engineering, but her determination and persistence won over her father's decision. She recalls *'This experience was difficult and frightening, but I learnt to approach people who could help me'* Subsequently, she studied at Indian Institute of Technology (Delhi) in 1981, which at the time accepted only 0.5% of all aspiring applicants based on a national exam. Entrants to IIT were mostly male, a gender ratio of 1:50 of women to men. The science talent scholarship from the early years paid for the preparatory course and exam fees. So all in all, national level scholarships, inspiring lectures from scientists, fee waiver for A-levels built the foundation for her subsequent education and career were the necessary steps which set the stage for later life.

After completing her undergraduate studies in India, she was awarded a teaching assistantship and fee waiver to study for a Masters and PhD in Tulane University, USA, followed by a prestigious post-doctoral position at The Swiss Federal Institute of Technology which she describes as '*an extremely fruitful professional and personal experience in Switzerland, until now, the high point of my scientific learning career'*. She moved to Newcastle upon Tyne, UK in 1994 to take up a lectureship where she had the opportunity to further develop her interest in fabricating new materials for electronics and she worked actively to develop new processes and technology to fabricate micro-electronic devices. This interaction led her to obtain a Royal Academy Industrial Placement at an industrial partner in 2001. Her interest in solving electrochemical materials engineering has been the driving force behind her successful progressive career at Newcastle University, leading to promotions to a Readership in 2000, and subsequently, a Personal Chair in 2005, followed by invitation to the Buckingham Palace in 2006. Her engagement in these issues inspired her to develop international symposia and collaborations (visiting chair, Waseda University, Tokyo, 2008, and NEERI, India 2009) as well as an elected Fellowship of the Institute of Metal Finishing.

Throughout her personal and professional life journey, Sudipta has had support from family, colleagues, transfer officers at Newcastle University, as well as from funders and investors such as EPSRC, Royal Society, Royal Academy, European Union, Regional Development Agency (ONE NorthEast) and NSTAR who she believes have play key roles in both her successful scientific academic career and the development and commercialisation of EnFAce non-technology that has led to the establishment of her spin-out company in 2010, ‘Royenface’

About the Innovation

Amongst the myriad of issues in micro-device manufacture, a major problem is related to fabrication such small scale structures. Since micron scale structures cannot be formed by standard engineering methods, micro-fabrication requires a step called photolithography.. Photoithography is a multi-step procedure which requires large amount of chemicals which ends up as waste. The process itself requires high-grade laboratory facility, which makes it expensive. Since each substrate requires photolithography, large quantities of waste chemicals are produced.. EnFACE technology uses an alternative method of microfabrication patterned tool which can be used to fabricate structures on numerous samples. The tool and sample are placed in close proximity in a pattern transfer system, where micro-patterns are fabricated. In order to achieve this novel chemistry, equipment and process variables are required. The original research started in 2002, and an initial filing for patent protection was sought in 2004. After passing through the UK and European patent examination, currently, it is in process of being registered in the US. At Newcastle, on the other hand, a new company has been spun out, Royenface to commercialise EnFACE. This is by no means the end of her invention, ongoing research is exploring other sectors where EnFACE can be exploited.

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