Synergetic Role of Chemistry in Women's Success

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ABSTRACT
Development and growth of a nation is determined by the effective utilization of human resources, both male and female. Though, female category is about half of world's population, they are underrepresented in most of the sectors. Chemistry is playing a synergetic role in shifting the equilibrium towards the women's success. It is the social responsibility to eradicate the gender bias in chemical related fields (academic, professional, industrial, and research). The mean and methods for the same are discussed in the present article.

Keywords: Chemistry, Gender Bias, Social Responsibility, Women Empowerment,

INTRODUCTION

As women number occupies half of the population, encouraging their abilities and brain-power makes the usage of these precious human resources, which is essential for the growth of technological and scientific fields [1]. Only 20 Nobel Prizes were given to women out of the 607 in sciences. Five, three and twelve were the number of awards in Chemistry, Physics and Medicine / Physiology respectively. Noble prize winners in Chemistry are Marie Sklodowska Curie (1911); Irene Joliot-Curie (1935); Dorothy Crowfoot Hodgkin (1964); Ada E. Yonath (2009); Frances H. Arnold (2018) [2]. At present, women's share in chemistry doctoral degrees per year is about 40% [3]. This article discuss about impact of society on women chemists, support to women in chemical education, women role models, recognition and awards to women chemists, importance of mentoring to women chemists and supportive measures from Governments and NGO's.

SOCIETY IMPACT

Scarcity of successful women chemists might be due to two reasons. One of it is the influence of societal training on them which confines attainments in a scientific profession. Unconsciously, societal training assigns the implicit goals for women like seeking out safety, acceptance and affection rather than success. It indirectly makes and propagates the women as acquiescent, non-assertive and non-competitive. Another reason is outdoor hindrances (i.e., overt and covert discrimination). It mitigates the chances of women achievement in competitive arenas [4].

Women must be trained for competitors and risk takers which lead them to success in chemistry. Hidden barricades are lying on the women progression path due to unspoken gender favouritism and / or discrimination or harassment in society in general, in educational / professional communities, in openings for career progress, in networking in operational conditions and guidelines, and financing opportunities [5]. Inspite of the societal barricades, some of the women were able to give their foot prints in the chemical field [6] (Table 1).

Table-1: Pioneering Women Chemists and their Contribution

Pioneering Women Chemists	Period & Place	Contribution
Marie Meurdrac	1610-1680, France.	First chemistry book written by a woman. Author of "*La Chymie charitable et facile enfaveur des dames*"

Emma Perry Carr	1880 – 1972, America.	The first Garvan Medalist. Studied UV spectral studies on simple unsaturated hydrocarbons
Rachel Lloyd	1839-1900, America.	First American female to earn a doctorate of chemistry
Ellen Swallo Richards	1842-1911, US.	First woman admitted to the Massachusetts Institute of Technology.
Yulya Lermontova	1846-1919, Russia.	First woman in the world to obtain a doctorate in chemistry and first woman to join the Russian Technical Association
Ida Freund	1863-1914, UK.	She was the first woman to be a university chemistry lecturer in the United Kingdom.
Harriet Brooks	1876-1933, Canada.	First Canadian female nuclear physicist and famous for her research on nuclear transmutations and radioactivity.
lcie Macy-Hoobler	1892-1984, US.	Researcher on "chemistry of nutrition", and was the first woman chairman of Biological Chemistry Division of the American Chemical Society.
Florence e.Wall	1893-1988, USA.	First woman to receive the medal of the Society of Cosmetic Chemists.
Gertv T. Cori	1896 –1957, US.	First Garvan Medalist and received a Nobel Prize in Medicine. Worked on the enzymatic synthesis of glycogen.
Christina C. Miller	1899- 2001, Scotland.	First female Scottish chemist and one of the first five women (also the) elected to the Royal Society of Edinburgh.
Marguerite Perey	1909-1975 France.	Physicist and radiochemist, a student of Marie Curie. First woman to be elected to the French Académie des Sciences

CHEMISTRY EDUCATION

A multiple regression path analysis shows that there is no direct effect of gender on course performance. However, noticeable sex difference was registered in chemistry course performance. Poor academic outcome in chemistry from female students was attributed to the weaker mathematics background. However, employing the female mathematics teachers at high school level helped the girls to exhibit better performance in computational tasks in comparison to boys, which was manifested in the improved score in scholastic aptitude test (SAT) score [7]. Enrolment of girls increases by recruiting more number of chemistry teachers and alteration in pedagogic procedures [8].

Few distinguished women chemists can be noticed in the history like Marie Curie who received two Noble prizes. She won the first Noble prize in Physics in 1903 along with her husband, whereas, the second prize awarded to her after eight years (in 1911) in chemistry. Deviation of women from the "academic track" is due to various complex influencing factors. Out of those, the prime reason is dearth of women role models and compassionate mentoring. Inspite of the arguments about considerable lack of female role models, information about some of the popular role models [8] is given in Table 2.

Table-2: Women Chemists as Role Models

Role Model Women Chemist	**Period& Place**	**Contribution**
Martine de Bertereau du Chatelet (Baroness de Beausoleil)	1600's, France.	Mineralogist and mining engineer
Elizabeth Fulhame	Late 1700s, Scotland.	Invented the concept of catalysis and discovered photoreduction
Madame du Chatelet	1706-1749, French	Proposed that fire and heat are not material, but, they are related
Marie Anne Pierrette Paulze (Madame	1758 born in France.	Translated the work of many contemporary British chemists into French

Lavoisier)		
Jane Marcet	1769-1858, London.	Author of "Conversations on Chemistry", which was a prescribed textbook in US and Great Britain for about 30 years.
Mary Sommervile	1780-1872, Scotland.	Author of "Connexion of the Physical Sciences"
Elizabeth Fulhame	1794, London	Author of "Essay on Combustion"
Anna Christina Persdotter Sundstrom	1795–1871, Sweden.	Laboratory assistant of Berzelius
Marie sklodowska Curie	1867-1934 Poland.	Pioneering researcher on radioactivity. First woman to win a Nobel Prize and only woman to win in two different scientific fields.
Laura Linton	1853-1915, America.	American chemist and physician, as a chemist she worked on analysis of asphaltum.
Helen Abbott Michael	1857-1904, America	American scientist who was among the first to study the relation of chemical composition to species of plants and to plant growth.
Agnes Pockels	1862-1935, Germany.	A German pioneer in chemistry. Her work was fundamental in establishing the modern discipline known as surface science
Mary Engle Pennington	1872-1952, USA.	Bacteriological chemist and refrigeration engineer
Willey Glover Denis	1879-1929, USA.	Apioneer in the field of clinical chemistry and the measurement of protein in biological fluids
Maude Lenora Menten	1879-1960, Canada.	Best known for her work on enzyme kinetics.
Edith Gertrude willcock	1879-1960, England.	Pioneering researcher with radium.
Ellen gleditsch	1879-1968, Norway.	Norway 's second female professor, Established the half-life of radium
Emma Perry Carr	1880-1972, USA.	Spectroscopist and a worldwide leader in the use of the ultraviolet spectra.
May Sybil Leslie	1887-1937, UK.	Worked on propertiesthorium and actinium. During World War I she worked on large-scale manufacture of explosives.
Stefanie Horovitz	1887-1942, Poland.	Known for experimental work proving the existence of isotopes.
Catherine Chamie	1888-1950, France.	Curie's assistant and worked on radioactive atoms.
Helene Metzger	1889-1944, France.	Mainly focused on the history of chemistry.
Icie Macy Hoobler	1892-1984, USA.	Biochemist who did research in human nutrition.
Dorothy Maud Wrinch	1894-1976, Argentina.	Attempted to deduce protein structure using mathematical principles
Ida Tackenoddack	1896-1978, Germany.	In 1934 she was the first to mention the idea later named nuclear fissionand one of the discover element rhenium.
Katharine Burr Blogett	1898-1979, USA.	Well known surface chemist.
Rachel fuller Brown	1898-1980,	Best known for developing the first useful antifungal

	Massachusetts.	antibiotic, nystatin.
Kathleen Culhane Lathbury	1900-1993, UK.	British biochemist known for her work with insulin and vitamins.
Erika Cremer	1900-1996, Germany.	German physical chemist, one of the most important pioneer in gas chromatography
Mary Fieser	1909- 1997 USA	Best known for the many books.
Dorothy Crowfoot Hodkin	1910-1994, Egypt.	Awarded the Nobel Prize in Chemistry in 1964.
Gertrude bell elion	1918- 1999, USA.	Biochemist and pharmacologist, who shared the 1988 Nobel Prize in Physiology or Medicine with others for their use of innovative methods of rational drug design for the development of new drugs
Rosalind Franklin	1920 – 1958, London.	Crucial contributor to the identification of the double-helical structure of DNA.
Ruth Arnon	1933- , Israel	A leading chemical immunologist
Irène Joliot-Curie	1897-1956, France.	Shared the Nobel Prize in Chemistry in 1935 with her husband, in recognition of their synthesis of new radioactive elements.
Ada E. Yonath	1939- 2009, Israel.	The Nobel Prize in Chemistry for studies of the structure and function of the ribosome."

In addition to introducing the role models of women chemists, the other avenues to make the girls competitive are setting goals to girls on par with boys, promoting their participation in team sports, inspiring towards chemistry and mathematics by conducting contests in those subjects, conducting seminars to offset negative approach that influence a bright career in chemistry, training the teachers to motivate the girls to have inclination towards scientific careers etc [4].

WOMEN IN CHEMICAL PROFESSION

Chemistry has been practiced by women since the initial times of documentation [9] (Table 3). Domestic duties made the women familiar to the separation techniques which are renowned part of analytical chemistry.

Table-3: Women Chemists of Ancient Era

Women Chemist of Ancient Era	**Period& Place**	**Contribution**
Cleopatra's	69 BC – 30 BC, Egypt.	Study of the solvent action of vinegar on pearls.
Tapputi	1200 BC Babylonian Civilisation.	Systematic and quantitative extraction procedures for preparation of perfume products.
Belatekallim and Ninu	1200 BC Babylonian Civilisation.	Extracted essences from plant sources by extraction and distillation
Fang	1st Century BC, China.	Extraction of silver from ores using mercury
Kleopatra Christopoeia	Third century AD, Alexandria.	Basic distillation still
Theosebeia	Third century AD, Alexandria.	Co-author of chemical encyclopaedia
Maria Hebraea (Mary the Jewess)	Third century AD, Alexandria	Devised new and improved alchemical equipment using glass (heating and distilling apparatus, *balneumMariae* / a double boiler), simple still (*kerotakis*) and complex distillation device (the

		tribikos). Proposed mercury as the deadly poison, mixed metal sulphide (Mary's Black)
Keng Hsien-Seng	975 AD, China.	Primitive Soxhlet process for camphor extraction using alcohol, extraction of silver from ores using mercury
Perrenelle Lethas	14th Century, Paris.	Reduction of silver ore followed by distillation of mercury

All over the world, women are in lag in comparison to men regarding recruitment, pay and promotion. In spite of limited number of female chemists in the history, an increasing trend in female students is recorded in the contemporary era [10]. Some of the women chemists feel that their career is diminutive due to male superiors who are jealous of women abilities, shun women, do not consider as a part of the work force. About 1/3rd of women are relocating after marriage due to career needs of husbands' or responsibility of child care. One of the difficulties faced by women chemists is working for long hours as per the employer's expectation. Scheduling is an issue for women chemist in the case of experimental research and to be successful, supportive family is essential.

Women claim that they are enforced to work hard than men to attain the equivalent career goals due to delayed acceptance of their experimental results, invisibility of women, either overlooking or underrating their work etc [11]. Another notion is that family issues inhibit the women to work for long hours as per the expectations of employers, whereas, men are not restricted from those hindrances.

FIGHT AGAINST GENDER BIAS

Gender inequality in fixation of speakers without inclusion of even a single woman for the scheduled International Congress of Quantum Chemistry, Beijing in June 2015 was exposed by Anna Krylov, Emily A. Carter and Laura Gagliardi. Protesting against the underrepresentation of women in respected positions at the conference, these three well known theoretical chemists called for a boycott. Responding to it, the president of the conference assured for gender balance [12]. However, Indian women chemists received moderate support to climb the ladders [13] (Table 4).

Table-4: Prominent Indian Women Chemists

Prominent Indian Women Chemists	Period	Contribution
Kamala Sohonie	1912 –1998	Pioneering Indian biochemist who in 1939 became the first Indian woman to receive a PhD in a scientific discipline
Asima Chatterjee	1917 –2006	Development of anti-epileptic drugs, and anti-malarial drugs. Conferred the prestigious Padma Bhushan and became the first female scientist to be elected as the General President of the Indian Science Congress Association. First female recipient ofShanti Swarup Bhatnagar award
Maharani Chakravorty	1937–2015	Well known Indian molecular biologist and worked on bacteriophage
Darshan Ranganathan	1941 – 2001	Pioneering worker in protein folding
H Ila nee Bhatnagar	1942	First woman to get a Ph.D. from I.I.T. Kanpur graduating in 1968
Seetha Coleman-Kammula	1950 –	Noted environmentalist and entrepreneur in petrochemical
ChitraMandal	1952-	A chemical biologist in the field of biomolecules and their applications in health and diseases. Former acting Director of CSIR - Indian Institute of Chemical Biology, Kolkata
AnjuChadha	1955-	Indian biochemist. She works in the fields of biocatalysis and enzyme mechanisms, green chemistry and biosensors.

CharusitaChakravarty	1964 – 2016	Unravelled quantum mechanical effects in the properties of atomic and molecular clusters
Seema Bhatnagar	1971-	Famous in anticancer drug discovery
Yamuna Krishnan	1974-	Youngest woman recipient of the Shanti Swarup Bhatnagar Prize

RECOGNITION AND AWARDS

IUPAC (International Union of Pure and Applied Chemistry) recognizes and encourages the research contributions of women with a history of leadership and/or community service. It distributes "Distinguished women in Chemistry and Chemical Engineering awards" for every two years since 2011, i.e., International Year of Chemistry Celebrations. Kim Baldridge (China), Donna Blamond (USA), Susan Bourne (South Africa), Janine cosy (France), Vicki Grassian (USA), Otilia Mo Romero (Spain), Elizabeth ann Nalley (USA), Carol Vivien Robinson (UK), Molly Shoichet (Canada), Luisa Torsi (Italy), Chris Willis (UK), Pernilla Wittung-Stafshede (Sweden) were awarded during the ceremony held at Paris in July, 2019 [14].

2011 was declared as the International Year of Chemistry and the same year matches with centenary of awarding Madame Marie Curie with Nobel Prize in Chemistry. Hence, the year 2011 has a special significance to recollect and respect the efforts of female scientists to pave a smoother way to the next generation, as well as to remember the contributions to science by women. On the eve, special editions dedicating to the Women in Chemistry were released by different journals like "*Australian Journal of Chemistry"* [15].

Women scientific awards are significant as they alert the scientific field about the presence of women scientists and hence enhance proficiency. In addition, those awards highlight women scientific work and help them to receive invitations for different professional activities. Garvan Medal is one of such award. Instituting such awards by other chemical professional bodies will assist the women scientists. American Chemical Society awards Garvan medals to women for distinguished service to chemistry since 1936. This identification of chemistry's creative women makes them to act as role models [16].

PROFESSIONAL BODIES AND WOMEN NETWORKS

Active participation in scientific women networks enables the members to help each other to reach career goals. To upkeep and stimulate the Women in Chemistry, a networking breakfast was conducted on 18th January, 2011 by women from forty four countries [17]. An open platform is provided by social media which facilitates the exchange of information. It was found to be advantageous for women to bring out deliberations regarding gender related problems in science. 'Women in Research' maintains its facebook account [18] by the women scientists of Max Planck Institute for Biophysical Chemistry, Germany.

Inspiring young women chemists to join some of the organisations (like AWIS – Association of Women in Science) are promoting equal prospects for female to move in to scientific professions and thereby accomplish their career goals [19]. Membership in professional organizations and active participation in their meetings keep the women updated to the cutting end technologies (Table 5).

Table-5: Women Chemists in Professional Bodies and Journals

Women Chemists	Period	Role in Professional Bodies and Journals
Lesley Yellowlees	2012–2014	First Female President of Royal Society of Chemistry (RSC).
Barbara Albert	2012–2013	First Female President of Gesellschaft Deutscher Chemiker (GDCh).
Thisbe Lindhorst	Current president	Gesellschaft Deutscher Chemiker (GDCh).
Livia Simon Sarkadi	2015–present	First Female President of Hungarian Chemical Society (HCS).
Supawan Tantayanon	2011–2013	First Female President of Federation of Asian Chemical Societies (FACS).

Anna Harrison	1978	First Female President of American Chemical Society (ACS).
Rachel Bodley	1831-1888	First woman member of the American Chemical Society.
Kathleen Yardley Lonsdale	1903-1971	First female member of the Royal Society in 1945.
Doreen Clark	1993	The first female national president of Royal Australian Chemical Institute (RACI).

MENTOR FOR WOMEN'S PROSPERITY

Participation of women in chemical sciences is encouraged by the support and environment extended to them. Role of mentors is significant in educating the women must have a career plan as a rule just like men. 'Virtue is its own reward' is the belief of many women and they wish to demonstrate themselves. Hence, they seldom choose a mentor. However, a mentor plays a key role to reach heights, in the modern era.

In academic, industrial and research fields, mentoring play a vital role to make out from underrepresentation women. Emotional support and inspiration are offered by the mentors, which build the confidence in women chemists and advices during the times of struggle and stress [20]. Existing gender disparity might be the cause for not having matching level and frequency of mentorship for female in various fields (academic, research, industrial etc) when compared to men. Taking into consideration of requirement of women mentorship towards academic / research / professional careers, initiatives were taken by different scientific societies. Based on focussing, mentoring organizations are classified into types, intramural and inter-institutional.

Intramural mentoring organizations mainly focus on creation of links among the people of an institution, while, inter-institutional organizations concentrate on connecting across institutions [3]. 'Committee on the Advancement of Women Chemists' (COACh) creates a platform to mentor the women scientists. It sponsors workshop on career orientation for women chemists working in academic field. Those workshops are aimed at skills improvement to enable their career growth and providing a network between participants and successful women chemists [21]. Chemistry Women Mentorship Network (ChemWMN) falls under latter category. It was formed in 2013 based on the breed idea during the telephone conversation between Brandi and Jillian. ChemWMN is aimed at providing inter institutional mentorship to graduate students and postdocs with the help of women faculty members, identified from matching areas. ChemWMN ensures the acceptability from the mentor by providing the brief details of mentee. In addition, carryout follow up activities like reminders about mutual check in, offering discussion point to endorse exchange, circulating network related news or career progression [3].

Similarly, WCC (Women Chemists Committee of American Chemical Society) is concentrating on career progress of women in chemistry related areas through monitoring of engagement, retention, etc [22]. Addressing harassment, advocacy, improving the scientific literacy, developing the resources to promote comprehensive scientific seminars are some of the themes in action plan of '500 Women Scientists', one of the grassroots organization which is aimed at empowerment of women in science [23]. The issues faced by women in science are advocated on national / international platform by AWIS (The Association for Women in Science). It is having chapters at grassroots level which help in networking and mentorship in order to improve groups among women in STEM [24]. Collaboration between National Center for Women & Information Technology and AnitaB.org had resulted in 'Mentoring-in-a-Box', a correlated mentoring toolkit, in order to upkeep specific mentee pairs [25]. One of the Swedish organization 'Women in Science' is aimed at helping women to achieve their goals by organizing mentor programs, workshops, seminars etc [26].

SUPPORTIVE MEASURES

Women are struggling to choose either family or endeavour for achievement in their career. Research career pursuance by women chemist is deterred by the birth and care of children. Some of the initiatives which address the issue are sanctioning paternity leave for working men which facilitates

them to share the new born responsibility and also to provide comfort to the working spouse. Some of the organizations are running on-site child to ease the mental encumbrance of working women about the care of toddlers [27]. Another relief is provision of flexible fellowships to researchers who are anxious to resume their research followed by a limited time gap due to family related issues. Some of the opportunities available for women chemists [28] are listed in Table 6.

Table-6: Available Opportunities to Women Chemists

Title	Subject Area	Opportunity Type	Organization	Age / Grade Range
ACS Women Chemist of Color Program	Chemistry	Network	American Chemical Society	Undergraduate and Professional
Priscilla Carney Jones Scholarship	Chemistry	Scholarship	American Chemical Society	Junior-Senior in Undergrad
Women in Science Project	First Year: All STEM, Sophomore: **chemistry**, physics/astronomy, computer science, engineering, and mathematics	Internship	Dartmouth University	Undergraduate

CONCLUSION

Though society has been showing the deterring impact on women chemists, they are striving towards their career goals with a support from various corners in the form of women reservation, inspiring women role models, specified recognition and special awards, cooperation from mentors and other supportive measures from Governments and NGO's.

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Table of Contents