Chemistry is a science well suited to the talents and situation of women; it is not a science of parade; it affords occupation and infinite variety; it demands no bodily strength; it can be pursued in retirement; it applies immediately to useful and domestic purposes; and whilst the ingenuity of the most inventive mind may in the science be exercised, there is no danger of it flaming the imagination, because the mind is intent upon realities, the knowledge that is acquired is exact and the pleasure of the pursuit is sufficient reward for the labour. (Edgeworth, 1795, p. 21)

INTRODUCTION

On north side of Stortorget in the old part of Stockholm sits the Nobel Museum, opened in 2001. The museum honors the awardees and summarizes their accomplishments on posters that move above the patrons on a ceiling track. Alfred Nobel (1833–1896) a chemical engineer famous for his invention of dynamite founded the Nobel Prizes. By the time of his death in 1896, he had 355 patents and when his will was read it came as a surprise that his fortune was to be used for Prizes in Physics, Chemistry, Physiology or Medicine, Literature, and Peace. Marie Curie (Nobelprize.org, 1903) is the only person to win two Nobel Prizes in separate fields of science and one of the few women to win any. Since the inception of the Nobel Prize in chemistry in 1901, 160 scientists have received the award, only four were women: Marie Curie in 1911 (Nobelprize.org, 1911), Irène Joliot-Curie in 1935, Dorothy Crowfoot Hodgkin in 1964) and Ada E. Yonath in 2009. The Nobel Prize in Physics has been awarded 104 times to 189 laureates, and of these, the only two women laureates are Marie Curie in 1903 (Nobelprize.org, 1903) and Maria Goeppert Mayer in 1963 (Nobelprize.org, 1963). The corresponding number of laureates who have been awarded prizes in physiology or medicine is 196 (for 101 times) with eight women. Only 2.5% of Nobel Prize recipients in the natural sciences or medicine are women, which is a low number that at the same time announces who might be predestined for a career and accolades in science and who might not.

The laureates’ autobiographies are posted on the official Nobel Prize (Nobelprize.org, 2011) web site. Starting in the late 1970s to an increasingly larger
extent these biographies have been written by the laureates themselves, giving a broader and more personal picture of the scientist and her/his achievements, than the descriptions given of earlier awardees. It is somewhat striking when reading the autobiographies of the female scientists who received the Nobel Prize before the 1970s, how these biographical essays differ from those of male awardees. For example, Marie Curie (Nobelprize.org, 1903) is described as being in possession of personal characteristics such as “quiet, dignified and unassuming,” characteristics that are not value neutral and are absent in the biographies of men. Another example is Maria Goeppert Mayer, Nobel laureate in Physics in 1963. Her biography states:

She is deeply indebted to Max Born, for his kind guidance of her scientific education. …

She was also employed by the Argonne National Laboratory with very little knowledge of Nuclear Physics! It took her some time to find her way in this, for her, new field. But in the atmosphere of Chicago, it was rather easy to learn nuclear physics. She owes a great deal to very many discussions with Edward Teller, and in particular with Enrico Fermi, who was always patient and helpful. (Nobel Lectures, Physics 1963–1970, 1972)

Such quotes convey a picture that women succeed in research because of patient and helpful men, and diminish women’s work and achievements with expressions such as “it was rather easy to learn nuclear physics.”

Some of the autobiographies written by the female laureates present a personal insight into the struggles of being a woman in academia with a desire and commitment to science. Rosalyn Yalow shared the 1977 Nobel Prize in Physiology or Medicine for the development of the radioimmunoassay (RIA) technique, powerful for detection of peptide hormones. In her autobiography she described how a part time position as a secretary to a leading biochemist, provided her an entrée into graduate courses, although she had to enroll in stenography. She studied physics and received A’s in two of her physics courses: an A in Optics and an A’ in the associated laboratory. When the Chairman of the Physics Department reviewed her record, he commented, “That A’ confirms that women do not do well at laboratory work.”

What about academia? Is the picture that appears above balanced by a more equal distribution of women and men in academic positions today, e.g., professors in science generally, and in chemistry specifically? We provide two snapshots, one from Europe, using Sweden as an example, and one from the USA. Sweden has a reputation as one of the most gender equitable countries in the world. Equality is a social aim influencing the society, through formal structures such as the Equal Opportunity Act (Swedish Code of Statutes, 1991, p. 433). Public as well as private work places are obliged to comply with the laws stated in the act. These laws influence policies impacting preschool to higher education, in both the Education Act (Swedish Code of Statutes, 1985, p. 1100) and in the national curriculum. In spite of these laws and policies, this same Swedish labor market is highly divided between the sexes, and academia reflects this pattern. In 2009, female professors in natural sciences at the five biggest universities ranged between 8.6 and 22%, and the prediction is that during the coming years the proportion of women professors will
decrease (Swedish National Agency for Higher Education, 2011). The participation of women in academic chemistry follows a similar trend. In Swedish chemistry doctoral programs, there is an equal distribution among female and male students, while in undergraduate education female students comprise about 60%. For the last 15 years, these percentages have remained consistent. But the proportion of women in positions as senior lecturers and professors decreases. The more prestigious the position, the fewer the number of women.

In 1972, the US government established Title IX Act states,

> No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance (U.S. Department of Labor, 1972, p. 1).

While the act has primarily been used to ensure women and girls equal access to education opportunities in the US, Government Accounting Office (2004) noted that the four key STEM (Science, Technology, Engineering, and Mathematics) funding agencies (Department of Education (Education), the Department of Energy (Energy), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF)) did not complete any monitoring activities as per Title IX requirements. Moreover, the agencies investigated complaints and provided assistance for grantees to comply with the Title IX act, only Education conducted reviews to ascertain if universities and grantees adhered to the act. Further investigation found that many scientists and engineers had the perception that Title IX dealt with providing persons equal access to sports, and did not understand that the act covered all education programs.

The NSF produces a yearly report on the status of women, minorities and persons with disabilities in science and engineering, but the specific data regarding chemistry is not accessible as it is reported as physical sciences. However, Corbett, Hill, & St. Rose (2008) conducted further analysis and in 2006, women attained 52% of undergraduate chemistry degrees and 34% of the doctoral degrees in chemistry. Nelson and Bremmer (2010) conducted a study that examined the participation of women in the top 50 departments chemistry departments. In 2007, in the same year, 21% of assistant, 20% of associate and 10% of full professors were women. Chemistry departments had a low utilization of women in assistant professor positions compared with the ‘pipeline’ of women with doctoral degrees in chemistry. A major concern with the image of chemistry is that its image is becoming increasingly diversified at the undergraduate and graduate levels but the upper echelons remain mainly male and white (Nelson & Bremmer, 2010). Further, 33% of the professionals in chemistry and materials science¹ and 13% of chemical engineers were female.

In recent years Swedish policymakers have promoted research within science, technology and medicine through targeted funding to “centers of excellence.” The Council for Gender Equality in Higher Education has recently evaluated these targeted efforts. The report, “His Excellency: About billion investments in strong research environments” concluded that the targeted research investments have
systematically disadvantaged women scientists, e.g. top qualified women are screened out in the application process and over time an estimated one billion Swedish crowns (about 160 million USD) of research funds have transferred from women to men (Sandström, Wold, Jordansson, Ohlsson, & Smedberg, 2010). Thus, fiscal resources are transferred from many researchers to a small, predominantly male, group. Often these researchers cannot spend the grants received which accumulates fiscal resources within their research groups and universities, rather than being disbursed to other researchers.

Moreover, the report questioned whether the excellence efforts are worth the price as the scientific quality and productivity declined in the vast majority of research groups that received the grants. The conclusion was that “In fact, there is no scientific support for the large and costly experiment that not only the Swedish government, but much of the western world, embarked on” (Sandström, et. al., 2010, p. 103, translated from Swedish by Hussenius).

In the United States, funding agencies have also moved towards funding collaborative grants involving multiple researchers at different career stages. No systemic review has been conducted; but men submit the majority of these large grants. Further disparity between women and men may occur in the US STEM research funding stream because larger grants are more likely awarded to research and higher ranked institutions where women are less likely to work (Hosek, Cox, Ghosh-Dastidar, Kofner, Ramphal, Scott, & Berry, 2005).

Printed Source of Chemistry’s Image

Looking at advertisements for higher education in chemistry and other natural sciences provides an idea of what image is held by and what kind of message is conveyed and disseminated by academia and society today. In a recent study, Salminen-Karlsson (2009) investigated higher education’s promotional materials, to see if the way different educational programs described themselves produced differences in recruiting students. She compared programs within two areas, caring professions and technical education as a number of projects have started recently in attempts to recruit more students of the underrepresented sex. Salminen-Karlsson (2009) found that in the university education brochures different words are used for similar phenomena. These different ways to depict programs, or abilities associated with the future profession, follow society’s perceptions of feminine and masculine traits and stereotypes. For example, girls are responsible and boys seek excitement and, women are content to do a good job that is easier while men make a career because of their expert skills and ability to express their ideas. The descriptions of caring profession educations include words and expressions with a feminine connotation and vice versa. In this way gender stereotypes and expectations are cemented and reconstructed.

In the spring 2011 the image of a full-page advertisement for chemistry education at a Swedish university was as follows: A picture dominates the page. In the middle of the picture, is a young man wearing a white lab coat and with untidy hair in an Einstein-like manner. He is the subject of the picture, looking straight
into the camera, straight into the eyes of the observers. He holds an Erlenmeyer flask containing a blue liquid. In front of him is a lab trolley with chemistry equipment; pipettes, round bottomed, volumetric and Erlenmeyer flasks, tripods and racks. All flasks containing colorful liquids of which some are bubbling and fuming. What is mediated is something that has a taste of a juggler’s tricks, e.g., what Edgeworth already in 1811 stated as something that should be avoided. This deep-rooted image of a chemist is an image that is found again and again in a variety of situations and contexts. But that is not all. In the advertisement, the young man, dressed in a lab coat is surrounded by five attractive, women dressed as flight attendants in suits and wearing high-heeled shoes. In the background is also a man dressed as a flight attendant. All are looking at the “chemist” with admiration in their eyes. The text beneath the picture says that you will get a flying start to your career by studying chemistry at the university.

Where does the image of the chemists come? The image of a mad, male scientist surrounded by flasks with colored liquids, boiling, bubbling and fuming. One should note that the 21st century scientist is no longer pictured by himself (sic) but has a cadre of admirers. The image itself is not new, but in an historical retrospective very similar to two apparitions specifically: the witches and alchemists. The view of witches is closely connected to herbalism, which is a traditional folk medicine practice that uses plants and plant extracts to treat and cure diseases and ailments. Such medical practices have occurred since Egyptian time ~3000 BC. The oldest written source is papyrus rolls such as the Ebers Papyrus from about 1550 BC, which is the most important one from a medical perspective. It contains about 800 prescriptions and mentions more than 700 domestic and foreign drugs (Göthberg 1982). At that time, physicians prepared concoctions and pastes of different textures as well as pills, ointments and plasters. The equipment they used was very similar to modern day tools: mortars with pistils, mills to crush the drugs, sieves, crucibles and scales, glass bottles or pots of earthenware stored the drugs.

In the Middle Ages, the power of the evil mastered people’s imagination, and the devil and his witches were the origin of disease and death. In several old churches from the 15th century are paintings of witches stirring in their pots. The ceiling paintings in churches were the bible for the illiterates, showing how people could be protected from the evil powers. There was also the evil itself illustrated and you could see what happened to the poor sinner. Those who were found guilty of witchcraft were severely punished and witch trials and burnings at the stake occurred until the late 18th century. The climax was reached in the middle of the 17th century when a wave of witchcraft trials went through Europe and New England. Although a witch in principle may also be a man, in 78% of trials the accused was a woman (Reis, 2003).

During the early Middle Ages, the cultivation of medicinal plants occurred mainly in monasteries. Monks and nuns engaged in health care and used knowledge from traditional folk medicine. The clergy had the literacy skills to preserve and disseminate this knowledge. But, this same knowledge among country people became a severe risk factor during the witch trials, and people with knowledge of herbal medicine were often suspected of witchcraft and sentenced to
burn at the stake. Most often women, so-called wise old female quacks who cured the peasants in the countryside with a mixture of superstition and knowledge of herbs and their medicinal properties, died because of their knowledge and skills.

Alchemy’s roots lie in Hellenistic Egypt built from a mixture of practical knowledge about metallurgy, pharmacy and glass making combined with the philosophical practice of analyzing and theorizing about the world. The alchemists searched for nature’s secret quinta essentia, which would give people the ability to transform base metals into gold. During the Middle Ages, unlike witches who were female, alchemy as a profession had high status and its practitioners were men.

Even today, the stereotypical image of a chemist continues to be an elderly man with an unkempt appearance and surrounded by flasks, bearing great similarities to ancient times’ images of witches and alchemists. Is this a surprising and totally wrong image? A very important and fundamental aspect of chemical activities is the engagement with experiments. And it is not just media and society around us that conveys the stereotyped image of the chemist; it is conveyed again and again by chemists themselves. It is also the image often presented by chemistry students when they participate in different types of recruiting activities to attract young people to choose the same education, career and future as themselves. The image shows what many of us perceive as the essence of our work: the work in a laboratory. The problem is perhaps that chemistry activities are much more diverse than this image. The picture is simplified and in a way an unfair image is not attracting young people today. A question that rises then is how do we want the chemist of today to be presented, in a credible manner without being nerdy/geeky and stereotyping?

The Chemist as a Poisoner

Although not chemistry’s most favorable image, historically (and still to this day) using poison to kill a person was regarded as one of the more sophisticated murder methods. In antiquity and middle ages, princes and lords did not feel safe from one meal to another, as placing poison in food was common. At that time professional poisoners existed and acted, and they also constituted a historic link to the image of the chemist.

Socrates was forced to drink the poisoned cup containing probably the juice of hemlock, mixed with opium and wine in 399 BC. According to Pliny this mixture was the Greeks’ means to execute convicted criminals. The active component of hemlock, conine, has a sedative, analgesic and antispasmodic effect. Six to eight fresh leaves of hemlock can kill an adult. After drinking hemlock a person would suffer a paralysis starting in the feet. The body temperature drops, skin discoloration occurs, and death is caused by respiratory paralysis. The poisoned person is conscious until death. The execution of Socrates is a real event, but you also find the use of poison in the literature such as in Shakespeare’s plays: Hamlet, Romeo and Juliet, or for example Macbeth in which the witches cook a strange brew of toxic herbs and other satanic ingredients. The portrayal of the three witches and their brew reflects the ingredients that people assumed were used.
Arsenic toxicity was known before Christ, and used during 1400’s and 1500’s by the families interested in attaining and keeping power and privilege such as the Borgias. Catherine de’ Medici tried to murder Henry of Navarre by wetting book pages with arsenic acid, so that the unsuspecting Henry, when he licked his finger to turn the book pages, was gradually poisoned. This technique of administering poison was used in Eco’s (1983) novel *The Name of the Rose*. Dorothy Sayers, Agatha Christie and Maria Lang are women writers who made great use of poison as a murder weapon in their crime fictions. In particular, Agatha Christie published some 80 detective novels and in more than half, poison was the method to murder people. Twenty-five of Christie’s books have a female killer and 22 of them used poison. She showed a great knowledge in the variety and diversity of toxins used. Christie was a trained nurse and in the beginning of World War I she worked as such, but from 1916 on, she was responsible for pharmacy and medicine distribution. And again she worked in a pharmacy during the World War II, which is where she most likely acquired her knowledge of poisons.

Utilizing chemistry to identify a murderer is often the theme of the plethora of television crime shows that foreground the use of forensic science, and in particular, chemistry. The popularity of these shows can attract and renew students’ interest in the subject. Universities with forensic science programs in their chemistry degrees recruit more students than other programs. Knowledge of chemistry may produce a poisoner, or the person who provides the evidence to identify a criminal.

**Female Chemistry Role Models**

In school chemistry textbooks, males dominate the images and text. Marie Curie is often the only female scientist mentioned (see below). Today, feminist historians and philosophers have increased our knowledge of the history of female scientists. Yet many of these women are still unknown to a broader population. Moreover, in recent decades most Western countries have invested human and fiscal resources into science, engineering and technology. A key assumption from policymakers and stakeholders is that women would choose science if they only understood how exciting and interesting the subject is. One strategy to achieve this goal is to include female scientists as role models in textbooks. Although the number of female Nobel laureates is low, Marie Curie is not the only example. Several of the physiology or medicine prizewinners are chemists and could be used to illustrate the close connection between biochemistry and medical improvements. For example, Gerty Theresa Cori (Nobelprize.org, 1947) a biochemist received the Nobel Prize in Physiology or Medicine in 1947 for the discovery of the steps in the catalytic conversion of glycogen. Gertrude B. Elion’s research produced important principles for drug treatment and development of medicines for treatment of diseases such as leukemia, anemia, hepatitis, rheumatoid arthritis and herpes, and to prevent rejection of transplanted organs. When Elion received the Nobel Prize in Physiology or Medicine in 1988 a colleague commented to her that she had done more for the humanity than Mother Teresa (McGrayne, 1993).
Other women’s contribution to chemistry could modify the discipline’s masculine image. Historically Mary Somerville (1780–1872; cited in Neely, 2001) is one of the few female scientists recognized in her lifetime by science societies. Although she could not participate in the institutions’ events, Somerville received one of Britain’s first state pensions for scientific activity. That a similar sum was awarded Michael Faraday was an indication of her reputation. Somerville wrote several science books that became widely used by the universities, yet neither she nor her daughters were permitted to study there. In Somerville’s 1834 book, *On the connexion of the physical sciences* she dedicated her book to women of her country, and no doubt she had a strong opinion of women’s intelligence, an opinion that may have been strengthened by the researchers, such as Faraday with whom she socialized. His interest in chemistry was originally inspired by the book of Somerville’s friend Jane Marcet called *Conversations on Chemistry* which became a bestseller when published anonymously in 1806 (Neely, 2001). Another reason for scientific women’s invisibility is that they, like Jane Marcet, had to anonymously publish their scientific work. It was undignified for a woman to publish under her own name. And several male scientists who received recognition for their discoveries worked closely with their wives, sisters or other female relatives or friends. Men have had access to the academic arena, where women have been banned. Mary Somerville never became a member of the Royal Society, and was an exception as she signed her books with her own name. Somerville’s husband was not a scientist but could enter the science society’s institutions. He borrowed books from the science library and he introduced her to researchers that he, but not she, could meet at the institutions (Neely, 2001). If Somerville had been married to an eminent scientist, her work would have probably merged with her husband’s and presented as his work. That was the usual story, with examples of a famous male scientist with a publicly unknown wife include Albert Einstein and his first wife Mileva Maric, Antoine Lavoisier and Mari-Anne Paultze, and Louis Pasteur and Marie Laurent.

Historical examples of female chemists can often broaden the stereotypic image of a chemist and the work that characterizes chemistry. The historical canon includes the story of the brilliant, lonely man who has contributed to major scientific discoveries, and paradigms shifts (Harding, 1986). This image of a natural scientist as a genius may have an exclusive function in the sense that there is a hidden message stating that not everyone can or should engage in such activities. An extraordinary talent is needed and teachers conveyed implicitly or perhaps even explicitly this message (Lemke, 1990). In the biography of Barbara McClintock and her genetic research, Keller (1983) showed that objectivity and rationality could be complemented with sympathetic understanding and emotional commitment to provide a fuller description of natural science. Researchers like McClintock and Einstein pointed to the importance of *letting the material speak to you*. They argued that it was easier to make discoveries if you became part of the system rather than being an observer from outside, that is, you need to *feel for the organism* (Keller, 1996).

The role of vision in her (Barbara McClintock’s) experimental work provides the key to her understanding. What for others is interpretation, or speculation,
for her is a matter of trained and direct perception. McClintock has pushed her special blend of observational and cognitive skills so far that few can follow her. She herself cannot quite say how she knows what she knows. She talks about the limits of verbally explicit reasoning; she stresses the importance of her feeling for the organism in terms that sound like those of mysticism. But like all good mystics, she insists on the utmost critical rigor, and, like all good scientists, her understanding emerges from a thorough absorption in, even identification with, her material. (Keller, 1983, xxi–xxii)

Like McClintock pointed out the necessity of “feeling for the organism,” in order to change the image of chemistry, chemists could acknowledge the emotional aspect of their research and laboratory work and the connection that occurs between the researcher and her (sic) tools - the instruments, equipment, and chemicals, that provide the pathway to discovering new knowledge. There are chemists who are very skilled using certain instruments. The equipment becomes an extension of their bodies and is perceived almost as embodied, but the chemists have developed their skills such that the practical aspect of the subject is as important as the outcome of the handicraft. This image of the chemist may be perceived as equally nerdy as the common stereotypical view. However, compare the image of a chemist using her tools to produce knowledge with an artist, a painter. For a painter, the painting in itself is certainly a driving force and not just the idea of the finished painting. S/he would also have a strong emotional connection with the process and the material medium to produce the painting. Chemists can experience a similar emotional feeling with laboratory work, a feeling where the material speaks to, with and through the chemist.

*Representation of Chemistry in Textbooks*

Another aspect of the image of chemistry is the way the subject is presented in textbooks. For over 50 years, researchers have studied the pictorial and written representation of scientists/chemists in all forms of textual materials and also asked students their perceptions of scientists through verbal and pictorial representations (Chambers, 1983; Mead & Metreaux, 1957). In a study of 10 Turkish middle school and 10 chemistry books, Kahveci (2010) found that in the high school chemistry textbooks, males dominated the images and text and Marie Curie was the only female scientist mentioned. Turkey supports textbook adoption, thus teachers would have to introduce other materials to counteract the masculine image of chemistry. Similarly a study of lower secondary science textbooks used in Brunei noted that males were overrepresented compared to females in the images and diagrams (Elgar, 2004). More recent studies suggested that the stereotypic images of a chemist as white and male have a negative impact on girls’ attitudes and achievement. But when girls are presented with a counter image of a chemist during science lessons their science anxiety decreased and achievement increased. So teachers may consider counteracting the stereotypic image of a chemist by introducing photographs and other textual materials that highlight women in the discipline (Good, Woodzicka, & Wingfield, 2010). Researchers have also suggested that making explicit connections of chemical
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concepts to the ‘real world’ and ‘authentic events’ is another approach to changing students’ image of chemistry from a subject that is done by eccentric white men wearing white laboratory coats, to a discipline that is important to humans, their environment and the worlds they live in (Glaser & Carson, 2005). The modification of textbooks has included information about ‘chemistry in action’ that is presented in a framed box with the text, or ‘boxed essays.’ However, if used as an authentic learning task, on-line resources such as Chemistry is in the News can provide students the opportunity to expand their image of chemistry and chemists. Younger students may develop their perceptions of scientists through trade books that are often used to teach science in elementary school. These text sources also reinforce the stereotype of the scientist as male, white and dedicated to his work (Ford, 2006). Texts often portray the scientist in a heroic stereotype—a white male that is incredibly smart, and if a female then an additional characteristic is she is hardworking (Milne, 1998).

**Students’ Attitudes Towards Chemistry/Science**

There are few studies directly examining students’ attitudes towards chemistry. In 2006, PISA (OCED, 2009) noted that while 93% of students viewed science as important to their lives, only 57% saw it as relevant. Students’ interest in science declines throughout schooling but when this is examined at the discipline level students’ interest in chemistry declines more than for biology, and this is particularly true for girls (Krapp & Prenzel, 2011). A recent study in England and Wales found that when asked if chemistry was a favorite lesson, 85% of 11-year olds said yes, 75% of 14-year olds and 65% of 16-year olds also agreed with the statement. The authors concluded that the students enjoyed the practical work associated with chemistry. While, chemistry started with a higher popularity than biology or physics with 11-years olds, there is a significant decline in students’ interest in the subject between ages 11–14 and more than boys are interested in the subject. Girls were more likely than boys to report that they saw little relevance of chemistry to their lives (Bennet & Hogarth, 2009). A similar pattern held for 79 American high school students, while there were no significant differences between girls and boys liking of biology, there was a significant difference in ‘liking chemistry’. Boys reported higher preference to study chemistry than girls (Miller, Slawinski Blessing, & Schwartz, 2006).

In her study of German ninth graders, Nieswandt (2006) examined their attitudes towards chemistry as a discipline, not how the students experienced the subject in a class. The students were surveyed, and reliabilities for the scales ranged from .70 and .83. Students who had a positive perception of their success in chemistry along with a strong interest in chemistry had a deeper conceptual understanding of the subject. Another attitude survey instrument was developed to examine Greek students’ difficulty (6 items), interest (9 items), usefulness of chemistry course (3 items), and importance of chemistry (5 items) (Salta & Tzougraki, 2004). Given to eleventh graders, students answered questions on a five-point Likert scale. The subscales had the following reliabilities: difficulty (0.87), interest (0.89), usefulness (0.71), importance (0.61). The sample had 576
student who were enrolled in one of three categorizations: 1) science-medicine, 2) humanities and 3) engineering. At the college/university level, Dalgety, Coll & Jones (2003) developed Chemistry Attitudes and Experiences Questionnaire (CAEQ) to measure first-year university chemistry students’ attitude toward chemistry, chemistry self-efficacy, and learning experiences. The authors modified questions from previous attitudinal scales such as TOSRA (Fraser, 1978) and College Biology Self-efficacy Instrument (CBSEI) (Baldwin, Ebert-May, & Burns, 1999). The resultant instrument had three scales (attitude toward chemistry, chemistry self-efficacy, and learning experiences), with five subscales contributing to attitude toward chemistry. Those five subscales are attitude toward chemists, skills of chemists, attitude toward the role of chemistry in society, leisure interest in chemistry and career interest in chemistry. The attitude towards chemistry subscales’ reliability ranged from 0.72-0.93. The self-efficacy scale has a reliability of 0.96. The learning experiences scale was comprised of four subscales: lecture learning experiences, tutorial and tutor learning experiences, practical learning experiences, and demonstrator learning experiences whose reliability ranged from 0.84 to 0.90. Overall the CAEQ had an average reliability of 0.74. One study, by Dalgety and Coll (2006) utilized the CAEQ and found that students intending to enroll in a second year of chemistry have a significantly more positive attitude towards chemists and leisure interest in chemistry compared with students who did not plan to continue with chemistry. The students planning a second year also had higher mean scores on the self-efficacy scale. Students dropped out of chemistry during their first year, but there were no students who picked up the subject. Although programs of study required some first year students to study chemistry, these students were as likely as their peers who chose to study chemistry to indicate that they would enroll in a second year of the subject.

There is a gap in the research on students’ attitudes towards chemistry and science. Increasingly, Western countries are becoming ethnically and racially diverse. While there are equal numbers of girls and boys engaged in chemistry at the high school level, the field has not examined participation patterns from a racial perspective. White students remain the dominant group in chemistry. Moreover, with the recommendations that teachers provide students the ‘real-world’ applications for chemistry these examples should be provided in a socio-cultural context. Recent studies have examined students’ perceptions of scientists and scientific practices but that work focused on biology, a discipline that has for several decades has attracted and retained students’ interest.

FEMINIST/GENDER STUDIES AND CHEMISTRY

The image of chemistry remains male, and those who practice the discipline, especially at its highest ranks remain largely male and white. In contrast to mathematics, physics and biology, there are very few feminist critiques of chemistry either from feminists from within the discipline or from those who offer critiques from a standpoint perspective. In a recent autobiographical book, several women chemists described their experiences as chemists and chemistry educators
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in the USA. Gilmer (2010) and Lewis (2010) both used the wind as a metaphor to describe their experiences as chemists. For Gilmer, the wind in her face was stimulating but also represented the men who acted as obstacles and obstructions to her academic career in chemistry. While Lewis viewed the wind metaphor as wind in her back, something that helped propel her forward and change her direction away from that of a scientist who was a role model for younger students interested in science because she now is a science educator and collects data from people and not molecules.

Over a decade ago in the USA, a group of senior women chemists and chemical engineers formed COACh (Committee on the Advancement of Women Chemists, n.d.) because of their “common concern about the gender-based obstacles women scientists face in trying to attain their career goals.” The group has developed workshops to provide female chemists with professional skills, established networks and mentoring programs and conducted research on the barriers to female chemists’ careers. This comprehensive and extensive effort to change and challenge the image of chemistry in the United States from male and white could also benefit from feminists outside of the discipline to engage in the theoretical work to understand why the image of scientist remains stereotypically a chemist… a chemist who is male, white, with unruly hair and very heroic.

NOTES

1 Data are reported as combined, that is chemistry and materials science.

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