Grau de Química

Treball Final de Grau

Gender perspective in the subjects of the Chemistry Degree of the University of Barcelona: contribution of women to the curriculum of the Degree.

Perspectiva de gènere en les assignatures del Grau de Química de la Universitat de Barcelona: contribucions de científiques en els continguts del Grau.

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Courage is like a habit, a virtue: you get it by courageous acts. It's like you learn to swim by swimming. You learn courage by couraging.

Marie Maynard Daly

Vull agrair a tots els docents que, al llarg de la carrera, m'han fet sentir part de la ciència i han col·laborat al desenvolupament del meu sentit de la curiositat. M'han format com a professional però també com a persona amb esperit crític. En especial a la tutoria rebuda, que m'ha fet creure en aquest treball i en la importància del mateix, gràcies per oferir la possibilitat d'acabar el grau de la manera més satisfactòria. També a la meva família, que m'ha acompanyat durant tots els anys de formació i especialment ara. Finalment dedicar aquest treball en definitiva a totes les dones que m'envolten, amigues, professores, àvies i mare, gràcies per ser referents.

REPORT

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1. SUMMARY

Gender inequality is a systematic and intersectional phenomenon in which we find discrimination acts inflicted upon a subject, established on a sex-based hierarchical structure. This inequality is directly nourished by the sociocultural roles and stereotypes assigned to women and men since their birth. This is built by a construction of rules, procedures, values and behaviors that frame the appropriate collective principles of women and men belonging to the system. Experimental science, within this system, is instituted as a historically masculine practice and even nowadays carries these roots. This is clearly reflected both in the professional scientific world, with difficulties in accessing decision-making positions or scientific recognition, and the education environments up to university level, where it is often difficult to feel a sense of identity or belonging for the female students. In order to eradicate this bias, an effective small-scale practice is to include gender perspective in the classroom through mentor figures. In order to carry out a diverse investigation, a brief temporal journey through the history of Chemistry is presented as an introduction, giving exclusive space to representative female scientists of this discipline and covering different branches. A selection of these figures with respect to the teaching plans of the Chemistry Faculty at the University of Barcelona, provides an approach to actively integrate gender awareness with three fundamental objectives: improve the visibility of women in science, raise awareness of gender bias and implement new focused training activities in the classroom. Besides examples and some general considerations to take into account, three detailed activities, which can be included in theoretical subjects as well as laboratories, are proposed: two activities based on the scientific work of chemists Agnes Pockels and Kathleen Lonsdale, and one with a more generic approach that contributes to the sensitization of the issue.

Keywords: Gender, chemistry, inequality, visibilization, referents, women, stereotypes.

2. RESUM

La desigualtat de gènere és un fenomen sistemàtic i interseccional en què es produeix una discriminació i jerarquització per raó de sexe. Aquesta desigualtat es nodreix directament dels rols sòcio-culturals i estereotips assignats a dones i homes en néixer, una construcció de normes, procediments, valors i comportaments que emmarquen l'ideari col·lectiu adequat de dona i home per pertànyer al sistema. La ciència experimental, en aquest sistema, s'instituеix com a una pràctica històricament masculina i encara en l'actualitat arrossega aquestes arrels, plasmades tant en el mon científic professional, amb dificultats per accedir a posicions de presa de decisions o de reconeixement científic, com en l'educació fins al nivell universitari, on sovint costa sentir-te identificada i pertànyer. Amb motiu d'eradicar aquest biaix, una bona pràctica a petita escala, és incloure la perspectiva de gènere a les aules a través de figures referents. Per tal de fer una recerca diversa, es presenta, a mode d'introducció, un breu recorregut temporal per la història de la Química, donant espai exclusiu a científiques representatives d'aquesta disciplina i abastant diferents branques. Una selecció d'aquestes figures respecte als plans docents de Química a la Universitat de Barcelona, dona pas a integrar activament la sensibilització de gènere amb tres objectius fonamentals: la visibilització de les dones a la ciència, la conscienciació del biaix de gènere i la implementació a l'aula d'accions i noves activitats formatives en gènere. A més d'exemples i algunes consideracions generals a tenir en comte, es proposen tres activitats detallades, per a incloure tant a assignatures teòriques com a laboratoris: dues basades en el treball científic de les químiques Agnes Pockels i Kathleen Lonsdale, i una altra de més genèrica, que contribueix a la sensibilització.

Paraules clau: Gènere, química, desigualtat, visibilització, referents, dones, estereotips.

3. INTRODUCTION

The word perspective refers to a specific point of view or a way of approaching a given situation. Speaking of gender —and understanding gender as a binary concept, man/woman—it is about analyzing the way we believe how both genders should behave, according to the social reading where they fit in. For example, we associate woman with taking care of family, while the idea of man goes to work and has other occupations and interests. In other words, we expect the person read socially as a woman to have concrete characteristics (often related to breeding and education) while the person read socially as a man, is attributed almost completely opposite traits (related to strength and logic). These associations end up translating into social inequalities of all kinds.

This context reveals the reason why historically there has not been many women in positions of power. Women have been taught, by the social and cultural limitations, to focus on caregiving and forget about study, professional careers and have prevented them exploring certain areas of knowledge. From this point of view, it is logical that our conquests have been more modest than men's. Moreover, the systematic invisibility of female voices as they are considered less valid, secondary or inferior, we have a perfect breeding ground for which women's look has been ignored and despised for centuries. This is the reason why the story of many great women has not reached our days.

Therefore, gender perspective allows us to analyze the way social systems are created and maintained from a certain point of view of sex, gender and sexual orientation: the androcentricity. We need to recognize, then, that the way we understand and read gender depends directly on the temporal context we are analyzing and the society we live in. It generates a great influence on work, career and relationships between men and women. The basis of the gender perspective is the search for equality to avoid situations of marginalization, violence and injustice.

Concretely in science, even since pre-university studies, the clear differences in the number of female students in university degrees and later STEM (Science, Technology, Engineering and Mathematics) degrees are known. With consequences such as difference in salaries, awards, recognitions and the lack of women holding high-level positions and management.

This bias is due to many causes: conciliation, opportunities, social position, race, education, beliefs, lack of references… it is a problem, then, that must be attacked in a cross-cutting way, from all possible points. Education, however, is the key to the development of judgment and the empowerment of students, especially in college, once the decision to pursue science is made. For this reason, and according to the "*Marc general per a la incorporació de la perspectiva de gènere en la docència universitària"* of AQU Catalunya, specific training with guidelines and recommendations is needed to avoid gender bias, for teachers and students, in all the elements around which the teaching in the university is designed, and to the later professional recognition (AQU Catalunya, 2018).

It may seem peculiar, as we are addressing a context in which, on the one hand, the presence and visibility of women is reduced (environments are highly masculinized) and, on the other hand, given the contents of science degrees, they do not suggest being easily taught from a gender perspective. Scientist women's work is often underestimated, or sometimes attributed to their male colleagues. For this reason, it is essential to make visible the contributions made by women to the discipline, as that would generate reference models for society and awakens scientific vocation in young women.

In this work, two objectives are set: firstly, bibliographic and historical research and a subsequent analysis of significant contributions by scientist women in the field of Chemistry. And also, as a second objective, training activities and workshops are proposed to relate these women and their contributions to the programs of the different subjects included in the teaching plan of the Degree in Chemistry at the UB, managing to normalize the presence of women in science and eliminating the androcentric vision that predominates, specially, in the field of chemistry.

3.1. BIBLIOGRAPHIC RESEARCH

It is already known that is essential to foster innovation in science, in order to develop more effective and diverse research to improve society's quality of life, therefore, to increase researchers and science professionals as well as rise the investment in science is a need to reach that goal. Hence it is important to motivate those who start their line of work around science to continue their careers. Women, concretely, tend to remain in the lowest level or even leave scientific field, and that motivation is specially necessary: in University of Barcelona, despite the fact that represent almost the 60% of doctorates, only the 41% are head of research projects (Universitat de Barcelona, 2020) and in public universities in Spain only the 7% are Professors (Ministerio de Universidades, 2020).

The role of women in the development of the sciences hasn't been fully recognized until last century. Constant discrimination and humiliation like the banning of certain institutions (universities, societies...) or only allow ancillary roles for women were faced by female scientists during their careers. Nowadays, the legacy of the past is present, even the great relevance of women in chemical field. Looking over history, we find out an erasure of women in science, and concretely in chemistry, a hole only disturbed by mere anecdotes, women's work concealed by masculine names or legendary Marie Curie. The truth is history of chemistry was written by men to be read by men, there is only one perspective.

That inequality has been determined by cultural role associated to women, the biological function of reproduction, her dedication to family, and even a belief on their intellectual abilities or intelligence. (Whaley, 2003) As a consequence, both their academic training and their presence in spaces dedicated to the production and dissemination of knowledge have been quite limited. Nevertheless, literature about woman in chemistry can be found in detailed research, fact that proves the active involvement of certain privileged women in science, despite the hostility that meant for men.

3.1.1. Review on history of chemistry with gender perspective

Who were those women that paved the way for us? Let's go on a little trip to the history of chemistry including gender perspective, to analyze, principally, the main contributions to the degree and the historical context of each scientist.

3.1.1.1. Antiquity to XVII Century: Alchemy and Early Chemistry

Between the III century B.C. and the 16^{th} century A.D. chemistry was dominated by alchemy. Alchemy's investigation goal was the search for the Philosopher's Stone, a hypothetical method capable of turning metals into gold. In alchemical research new chemicals and methods for the separation of chemical elements were developed. In this way, the basis for the development of a future experimental chemistry were established.

As a contextualization and example, around the fourth century B.C. in the Greek polis, women's activities were reduced to the domestic job. Hardly any profession could be practiced by them nor own possessions or have authority on their own children. Even the citizen status was stripped (Adela Muñoz Páez, 2013).

Not long after, Tapputi-Belatekallim is known to be the first alchemist. She lived in Mesopotamia date from 1200 B.C. Her scientific activity was expressed in a clay board were distillation and extraction processes were described using plants as raw material. But the real first documents written by women about chemistry didn't come out until Mary the Jewess. She lived between 1^{st} and 3^{rd} centuries A.D. in Alexandria, and although her writings haven't survived, she is found credited in "*The Dialogue of Mary and Aros on the Magistery of Hermes"* which for the first time reports acid salts.

Her inventions are her main contribution to the discipline: *Tribikos, Kerotakis* and *Bain-marie*. Which show similarities to contemporary lab material used in distillations or extractions and a soft heating method.

As women issues didn't concern men scientists, the first chemical documents written by women usually talk about subjects of interest for them, for example cosmetics, and many more also suffered difficulties, sometimes branded as sorceresses or witches.

Moving on, in XVI and XVII Centuries, after Middle Ages period, Isabella Cortese, in Italy, writes "*Me secreti della signora Isabella Cortese"* (1561) were introduces alchemy to a wider public. In the book are found medic remedies and cosmetology.

From the XVII century on, chemistry starts to constitute as an experimental science with an independent objective and goal of philosophy and alchemy, two disciplines linked to chemistry up until then. Some women in science started to talk about gender equality in the discipline, some examples are Marie le Jars de Gournay, in her work "*Egalite des hommes et des femmes"* (1622), and the French chemist Marie Meurdrac, that wrote "*La chymie charitable & facile, en faveur des dames"* (1666), in which she wrote, in addition, about alchemy, chemical process to obtain remedies and cosmetics, metals, and warnings on some of the toxic chemicals used, such as $HgCl_2$, a component used in whiteners for skin.

3.1.1.2. XVIII to XIX Centuries: Modern Chemistry

From the XVIII Century on, chemistry definitely acquires the characteristics of an experimental science. Careful measurement methods are developed and allow a better understanding of some phenomena, such as the combustion (withdrawal from the phlogiston theory) and finally lay the foundations of modern chemistry.

At the beginning of XVIII Century, the work of most of the female scientist was based on scientific dissemination: either translation of texts, lab assembly's drawings or lab assistant to their male colleagues (often their husbands), but always secondly, holding the indirect position in the experimental research. Some relevant figures of that period are Anne Marie Perriet Paulze — overshadowed by her husband, Antoine Lavoisier — and Jane Marcet, who both work in the dissemination field.

Elizabeth Fulhame starts to take up a direct and active position in chemistry and didn't carry out her research in collaboration with any man, which makes her work singular among female chemists of the century. In 1794 publishes "*An Essay on Combustion with a View to a New Art of Dying and Painting, wherein the Phlogistic and Antiphlogistic Hypotheses are Proven Erroneous"*, which was her main contribution to chemistry. In it, she states the fact, among others, that metals could be reduced at room temperature in aqueous solution without the need to heat them to high temperatures with coal. These discoveries ended up opening new fields in chemistry: kinetics, photochemistry and catalysis. (Fulhame, 1794).

The maturity of the discipline as a modern science was reached at the end of the XVIII century. In order to imitate nature, chemists began to wonder if natural substances could be generated in the laboratory and obtain unnatural substances that could improve the properties of the natural ones. From these investigations arises the area of chemical synthesis.

In the first half of XIX century, the most relevant female figures in chemistry are Julia Lermontova (petroleum and oil company research) and Agnes Pockels, founder of surface chemistry. Her works were recognized by Rayleigh as well as by Langmuir, who, instead of Pockels, received the Nobel Prize in 1932 for her work on monolayers. Katherine Blodgett was also a pioneer in surface chemistry and worked hand in hand with Langmuir to perfect Pockels's work. Her main achievement was the nonreflective glass invention.

In the second half of XIX century and the very beginning of XX century, the famous Marie Curie carried out her scientific work: development of the theory of radioactivity, (a term that she coined), discovery of techniques to isolate radioactive isotopes, and the identification of two elements, polonium and radium. Later, in XX century, this work is carried on and perfected by her daughter Irène Joliot-Curie, whose main contribution was the discovery of the induced radioactivity. Alice Ball also represents a model regarding tenacity and spirit of achievement. Despite her short career in chemistry due to her premature death, she managed to develop an injectable oil extract, via esterification of the fatty acids, which was the most effective treatment for leprosy at that time. Besides her, another outstanding scientist of the century is Ida Eva Tacke, the first to mention the concept later coined nuclear fission and the discoverer of rhenium element.

3.1.1.3. XX to XXI Centuries: Contemporary Chemistry

As the XX century starts, there is a conceptual crisis in the world of Physics with the beginning of the Relativist Revolution and Quantum Theory, which indicate that a new postmodern epoch is being faced. In Chemistry there is no such transition, but indirectly it has been influenced by the regeneration in Physics as, historically, the development of Chemistry is directly related to the advancement of Physics, with no clear difference between both sciences in some fields. However, the development of Chemistry-physics and the chemical bond are specific issues to the advancement of Chemistry in this century.

There is a change in the objectives of science in general: the perspective of *reason* no longer predominates, and the sciences of *life* breaks through. Physics lose prominence and Biology, Biochemistry or Genetic Engineering gain it. All this affects Chemical research, as a science that supports these disciplines. Despite the contradictions and difficulties experienced in the XX century, which includes two world wars, it has been a century in which science and technology have made a great leap. In it, the atomic era, the age of synthetic materials, the conquest of outer space, the era of robotics and informatics, genetic engineering and the agricultural green revolution take-off, and in each of these conquests Chemistry is present as a basic science.

This century also brings an organization of science into institutions that concentrate their efforts on both fundamental and practical studies. Politicians realized, since the First World War, the need to finance the costs of research related to military technology. Even with the benefits that the institutionalization of science brought, women were left out of the formal surroundings of scientific construction and those aforesaid institutions. In Spain, scientific societies offered resistance to the entry of women in proportion to the power status of the concrete society: female scientists who had wide international recognition were rejected in the national Academies of Sciences (Magallón, 2011).

A great generation of chemists emerged, the fruits of which are still being gathered. Although we can find them in all branches of chemistry, most of them worked in the new branches of knowledge that emerged as a result of the discoveries of the late nineteenth century. Fields where scientific success is uncertain, women were more likely to make their way into them. After the discovery of radioactivity by Marie Curie in 1898, a new field of research was opened: the atomic nucleus, where several relevant scientists appeared. Some of the most brilliant were her daughter, Irène Joliot-Curie and the Austrian Lise Meitner, who developed a long career in this field, discovering the nuclear fission process. Lise was unfairly forgotten in the award of the Nobel Prize in Physics to Otto Hahn in 1944.

In Nazi Austria, 1944, chemist Erika Cremer sent to German journal *Naturwissenschaften* her first article that established the foundations for gas chromatography technique, but during the fall of the Third Reich it was lost and never got published. That same year, moreover, a bombing affected Cremer’s Institute, which obviously turned the context very tough. In 1952 chemists Archer J.P. Martin and Richard L.M. Synge were awarded with the Nobel prize for the technique invention, they didn't credit Cremer. It wasn't until 1976 when the journal *Chromatographia* eventually published Cremer's lost article.

Another research field that was tackled by women from the very beginning was X-ray crystallography. After the discovery of the phenomenon of diffraction in 1912 by the Bragg brothers, scientific women had access to the most powerful tool to understand the structure of matter. Among them were Katheleen Lonsdale, who figured out the structure of the diamond and tested, using X-rays, the planar structure of the benzene ring. Dorothy Crowfoot-Hodgkin, who won the Nobel Prize in Chemistry in 1964 for discovering the structure of penicillin and vitamin B-12, and Rosalind Franklin, widely recognized and unfairly forgotten in the award of the Nobel Prize in Medicine to Watson and Crick for the resolution of the DNA structure.

On the border between chemistry and biology there is biochemistry, dedicated to the study of molecules with vital functions in living beings. Israeli biochemist and crystallographer Ada Yonah won the Nobel Prize in Chemistry in 2009 for her work on the behavior and structure of ribosomes. In the synthesis field, a young discipline, some remarkable scientists were Gertrude Elion, who synthesized for the first time several drugs to treat leukemia, malaria and urinary infections, and Stephanie Kwolek who synthesized, in 1965, *Kevlar* a heat-resistant and strong synthetic fiber with numerous uses: bulletproof vests, bicycle tires or sails for racing sailboats.

In Spain, even being just a few, the group of pioneer women scientists has an important symbolic meaning, since they widened the spaces of female activity and presence in society. At the beginning of the century, Angela Garcia de la Puerta focused her thesis on *Contribution to the study of oxidation potentials* and afterwards worked on electrochemistry in various laboratories and as a teacher. Dorotea Barnés and her sisters (Adela, Petra and Ángela) are the best example of the privilege that the women of the epoch enjoyed when being educated within a liberal and egalitarian family. Except for Ángela, who took an interest in art and languages, the three sisters became scientist. Dorotea though, was one of the Spanish pioneers in chemistry, as she published in 1932 the first report in Spanish on Raman spectroscopy in the Spanish journal *Anales de la Sociedad Española de Física y Química* and introduced this technique in the country. Already at mid-Century Josefa Molera Mayo collaborated in the creation of the first gas chromatographer in Spain and introduced in the country methods of analysis for chemical reactions by gas-liquid chromatography.

The development of chemistry continues in the XXI century, and it is challenging to predict what direction will it take in the next few years. However, there are several areas of development that have proven to attract the interest of scientists. Some of them are the weak nuclear force, its role in the structure and organization of matter at a molecular level, the continuation of the computing explosion, energy systems: lithium batteries, hydrogen batteries, nanotechnology, the graphene revolution: "the super-material of the future"...On the other hand, problems such as overpopulation, pollution and environmental deterioration leave no room for doubt: chemistry will play a fundamental role in humanity's determination to achieve sustainable development. The effect that chemical substances and their massive use have on the planet already generated a great deal of interest in the past century, due to the problems caused, for example, in the ozone layer.

An undeniable contemporary referent is Carol V. Robinson for her pioneering work on advanced mass spectrometry. She has pushed electrospray mass spectrometry (ESI) to places thought unattainable. This technique allows to characterize samples of aerosolized drops, membrane proteins, which provides functions and structure (Sanderson, 2015).

Lastly, it is worth mentioning the 2020 Nobel prize in Chemistry which won Emmanuelle Charpentier and Jennifer A. Doudna owing to the CRISPR/Cas9 “genetic scissors”, which represent one of the sharpest tools regarding to gene technologies. This technique allows researchers to modify precisely animal plant and microorganism’s DNA, an unprecedented impact in biologic field as this tool contributes, for example, to the development of new cancer therapies.

4. CONTRIBUTION TO THE TEACHING PLAN

4.1. INTRODUCTION

A discrimination between men and women remains in many disciplines and must be treated in biological terms as well as in socio-cultural terms. In science, as long as products, policies or actions of the subject of study are imbued with such conditions, it is important to integrate gender perspective in university degrees, to a greater or lesser extent, depending on the topic of each subject in the course. However, there is a general consideration in science: the few spaces given to women, students as well as professionals, generate consequences such as the tendency to low involvement of women in the discipline (especially in experimental science). Gender stereotypes and a lack of references in pre-university and university studies, discourage women's scientific vocations and highlights these differences.

Traditionally, in abstract or theoretical scientific fields, the attempt at introducing gender perspective has been overlooked, taking for granted that the concepts and techniques expressed are gender neutral. However, language, metaphors, analogies, or iconography used as support can provide an androcentric view of reality and reinforce gender stereotypes, as relating individualism, competition and self-promotion to a masculine figure and caring, humility, and cooperation as female attributes.

Another example is the expected "researcher type" professional in science: it seems that history of science has been a linear sequency of discoveries made by lonely male geniuses by their own personal intellects. These expectations lead to think not only about the exclusion of women's contributions to science but ignores the current way of practice science nowadays: working in close collaboration with each other and in teams. Doctor Maralee Harrell explained about this phenomenon occurring in physics, people consider themselves to be less capable to contribute to a team when history doesn't include their collective. Women are not expected to be owners of physics knowledge, they don't fit in the social expectations about who a successful physicist is, and as a consequence, their work is systematically depreciated (Harrell, 2016).

In chemistry, it is necessary to emphasize the lack of female references in the subjects of the study program. After a brief review on the history of chemistry with gender perspective, some of the main contributions to the discipline are analyzed and related to each of the subjects in the core curriculum of the Chemistry Degree in UB (University of Barcelona) with the aim of creating referents, promoting equality, and shedding light on work often underestimated or sometimes attributed to male colleagues.

A wide search of female chemists and general scientists has been made according to the different epochs in chemistry history. In order to summarize this work, a few of these scientists and their work will be developed and analyzed below with the main purpose of getting to know them and bind their contributions and the study plan together. This selection is based on the context (birth country, race, purchasing power, access to education, historic time) and representative contributions.

4.2. AGNES POCKELS (1862-1935)

Born in Italy, Agnes Pockels is a well-known surface chemist who grew up and developed her career in Germany, when her dad, from the Austrian Army, was retired. After attending the Municipal High School for Girls, where she noticed her interest in natural sciences and physics, she would have gone further in her studies but, due to the socio-cultural context of the epoch, women were not allowed that privilege. Her younger brother Friedrich though, did attend University to study Physics and provided the books and material for her as self-taught. As the unmarried only daughter, at a very early age, she assumed the responsibility of nursing her ailing parents, and carry though the house chores, which gifted her the opportunity to observe surface tension phenomenon firsthand.

Surface tension, even being a macroscopic property, comes from intermolecular forces. Molecules in a liquid, pull each other depending on the electron distribution and shape (Figure 1). This pulling is caused by water’s polar property trough hydrogen bonds between atoms from different molecules. A water molecule sunken in a fluid, feels the other molecules of water pulling it, but the equitable distribution of the molecules surrounding, avoids the molecule to feel any force (they are cancelled one by each other). A molecule on the surface of a fluid, instead, only feels the pull of the other molecules below the surface and their surface neighbors, causing an imbalance that origins a net force: surface tension (Aldridge & Brar, 2020).

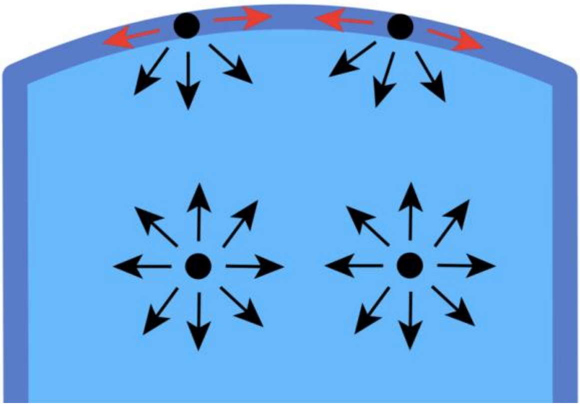

Figure 1: Surface Tension diagram.

(Via Wikimedia Commons with Public domain.)

In 1880, at age 18, Pockels begins her first experimental work on this phenomenon. She was interested in the behavior of the molecules when introducing a contaminator (surfactant), as soap of fats, in the fluid. In order to compare surface tension on contaminated liquid vs non contaminated, she built an apparatus using a small tray filled with water and a light metal partition to separate the tray in two sides. She coupled a ruler to the tray which allowed to measure the distance that traversed the metal partition. With the help of a scales, measured the force to lift a little disk off the surface (Turner, 2016) and then determined the surface tension dividing the force by the length traversed measured with the ruler. This apparatus, later called Pockels's trough and eventually called Langmuir-Blodgett trough (Figure 2 and Figure 3: U.B. Physical Chemistry Laboratory's Langmuir-Blodgett trough. an improved version based on Pockels's one that is currently on use, was carried out by Irving Langmuir and Katherine Blodgett.

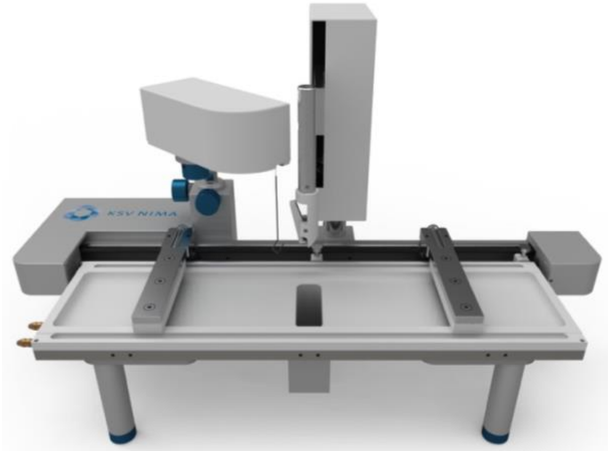

Figure 2: Langmuir-Blodgett trough.

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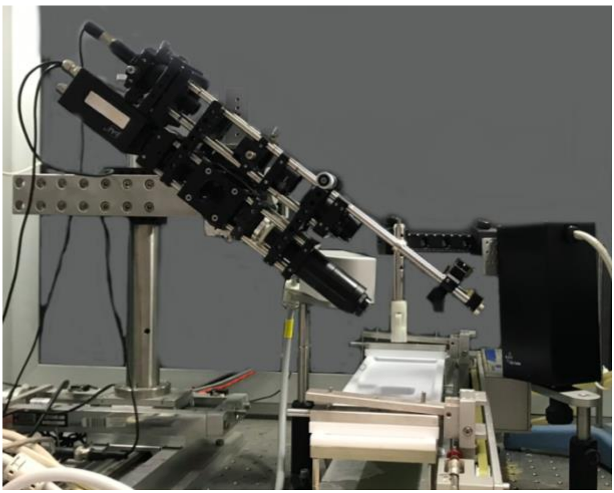

Figure 3: U.B. Physical Chemistry Laboratory's Langmuir-Blodgett trough.

After positioning the partition in different spots of the tray and measuring then how the surface tension varied with area, a pattern was found. With a fixed concentration of surfactant, the surface tension grew up as the area increased until a maximum, beyond which, the surface tension remained constant in spite of the area. In other words, in a small area, there is a high concentration of surfactant and that prevents water molecules to feel the pull of their neighbor molecules, thus the surface tension is low, while increasing the area causes a spreading of the surfactant and allows water molecules to interact which each other, raising surface tension. Eventually a molecular monolayer from the contaminant is formed on the surface.

Since her brother gave Pockels university material, she found an article about surface tension research by Rayleigh published in the German journal *Naturwissenschaftliche Rundschau* and decided to write a letter to him explaining her apparatus and observations and he forwarded the letter to Nature, that published Agnes's work (Pockels & Rayleigh, 1891).

Pockels continued to publish her discoveries and results from her surface tension work. In 1931 she was the first woman to receive the Laura R Leonard Prize from the German Colloid Society and in 1932 received an honorary PhD from the Technical University of Braunschweig. That same year, scientist Langmuir was awarded with the Nobel Prize in Chemistry for his investigations on surface tension using an apparatus based on Pockels's to prove the molecular monolayers.

The knowledge contribution that Agnes provided, are long-lasting in surface chemistry despite the obstacles faced due to her female condition and the historic context she lived.

Pockels's research work can be related directly to a couple of subjects regarding the Chemistry degree. In the initial phase, the subject *Basic Chemistry I* discusses the basic notions about polarity, intermolecular forces and an approaches to surface tension concept and liquid structure. Later on, *Physical Chemistry I*, the first contact with physical chemistry in the Chemistry Bachelor, extends a bit the elementary concepts studied before and, besides surface tension, also opens concepts as surface layers or capillarity. Regarding Laboratory practice, the courses *Physical Chemistry Basic Laboratory (PCBL)* and *Physical Chemistry Laboratory (PCL)*, tackle in a practical way surface tension, emulsions and colloids.

4.3. ALICE AUGUSTA BALL (1892-1916)

Alice Ball was an Afro-American chemist who fought against racial and gender barriers. When she was only twenty-three years old, she improved an existing and painful treatment for Leprosy, which would continue to be the most effective until 1940, twenty-four years after her death.

She was born in Seattle, USA, in July 1892, but due to family issues the family relocated in Hawaii. As her parents worked in photography, Alice started to learn about chemicals used to develop films at that time. After the death of her grandparent, Alice started high school in 1906 back in Seattle and after graduating, attended the University of Washington, where she became Chemist (1912) and Pharmacist (1914) and co-published the article "*Benzoylations in ether Solution*" in the Journal of the American Chemical Society (Ball & Dehn, 1914). In 1915 Ball graduates from her master studies back in Hawaii, where she became the first woman and the first Afro-American woman to graduate from the master's college in the University of Hawaii (Bleam, et al., 2007).

As she was teaching chemistry at the College of Hawaii, she was asked by Doctor H.T. Hollmann to work on the improvement of the current treatment of Leprosy with chaulmoogra oil, an extract from the plant *Hydnocarpus wightianus*. Leprosy was considered a very contagious disease in the early twentieth century. When the oil was applied directly on the affected epidermis, patients showed progress, which were greater when given orally, however, the oral administration was complex, as the oil had a strong flavor and many times caused emesis. Besides the discomfort of the patients, it was necessary to find a more practical and effective method of administering the oil. The challenge was to prepare the injection, but as the oil was quite insoluble in water and very viscous, the injection caused pain and abscesses. Alice prepared the ethyl esters of the active fatty acids that conform the oil: hydnocarpic acid (Figure 4) and chaulmoogric acid (Figure 5) via esterification, isolation and purification of the acids, forming a more easily injectable and less irritable liquid, as viscosity of the active compounds was reduced thanks to ethyl esters prepared by Ball (Wermager & Heltzel, 2007).

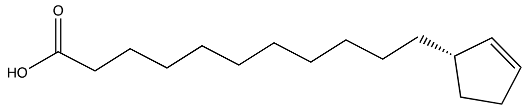

Figure 5: Hydnocarpic acid.

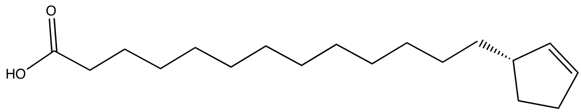

Figure 4: Chaulmoogric acid.

The active fatty acids in the oil are characterized by being hydrophobic and having long hydrocarbon chains. Her work started by treating the oil with a strong base as NaOH in order to break glycerol from the fatty acids and obtain the fatty acid carboxylate (saponification). To neutralize the base, acid was added, and free fatty acids were obtained, which were already less viscous than the oil. To purify the products, various recrystallizations were performed.

Acids still were quite irritant, so, at first, deprotonation of the acids to carboxylate and subsequent neutralization with sodium cation could be a solution but physicians were opposed to the use of the soluble salts for intravenous injections as may cause hemolysis —if the salts got into blood cells, the surrounding fluid would counteract diluting the salt by sending in some of their water until they burst—. Ethyl esters instead, were thin liquids that showed to be readily absorbed when injected (Dean & Wrenshall, 1921). To convert the fatty acids into their ethyl esters, Ball carried out the Fischer esterification, which mechanism is showed below (Figure 6). Ethyl esters of chaulmoogra oil were already purified in 1905 for the first time and first manufactured by Bayer in 1908 as antileprol but Ball figured out a more scalable method.

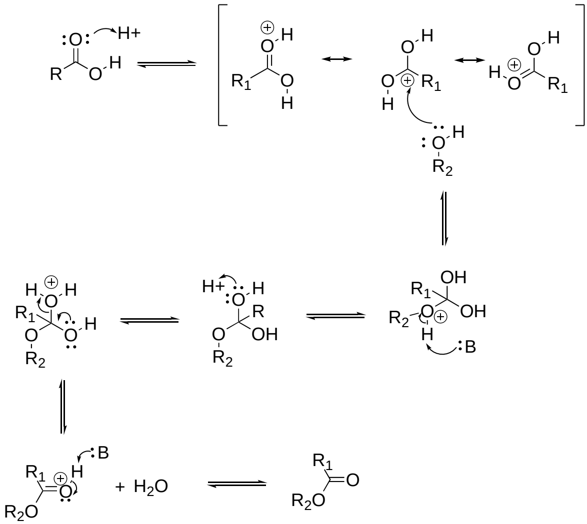

Figure 6: Esterification mechanism.

Unfortunately, Alice Ball died in December 1916 at the age of 24, so she couldn't publish her findings. Another chemist, Arthur L. Dean, who later became the president of the University of Hawaii, published her work and began to produce the injectable chaulmoogra extract (Wermager & Heltzel, 2007). Hollmann, after years of her death, published a paper in 1922 giving credit to Ball and referring to the injectable as the "Ball method" (Hollmann, 1922).

Her contributions to Chemistry discipline are various, but regarding the Chemistry Bachelor in UB, there is none direct involvement. Nevertheless, it is necessary to raise awareness on female scientists of non-Caucasian race, mostly erased in science. Her reasoning and chemical criterion indeed are basic in chemistry formation. Her work is mostly gathered regarding biology and organic chemistry. *Biology* is the most basic subject that addresses functions and structure of fatty acids. It is included in the degree's initial phase and concretely tackles lipidic biomolecules and its behavior. Later in the degree, the first subject that comprehends carboxylic acids and derivates is *Organic Chemistry II*, which includes the reactivity of the group. Concerning laboratories, Ball's method may be included in *Organic Chemistry Basic Laboratory (OCBL)*, in which experimental practice number 10 is about Carboxylic acids' chemistry, according to the study plan. As an add-on, Alice Ball knowledge is interesting to carry out other subsequent subjects, such as *Organic Chemistry III*, *Organic Synthesis*, which is an optional subject, and *Organic Chemistry Laboratory (OCL)*.

4.4. KATHLEEN LONSDALE (1903-1971)

Kathleen Lonsdale (née Yardley) was an Irish crystallographer born in 1903. She and her family moved to England when her mother got divorced from the father. In England attended school and high school and then signed up for University in Bedford College for Women. Henry Bragg turned out to be one of her examiners and he asked her to join his research group in London. She centered her work in X-ray crystallography, a newborn specialty, and turned into a referent in the field. Her first publication came out in 1924 under the title "*Tabulated data for the examination of the 230 space-groups by homogeneous X-rays*" (Yardley & W.T. Astbury, 1924). Later, she and Bragg's team moved to the Royal Institution in London.

In 1927, Kathleen was challenged by the English chemist C. K. Ingold to analyze hexamethylbenzene and hexachlorobenzene crystals. Eventually, in 1929, she achieved the solution these structures confirming the flatness of the benzene ring with the determination of the length of C-C bonds which were actually equal, hence showed coplanarity and hexagonal formation (Lonsdale, 1929). Hexamethylbenzene was actually the first aromatic compound structure defined by X-ray diffraction. The intensities showed from the main crystal plane suggested a planar order of the carbon atoms in the molecule. Lonsdale compared the intensity values obtained from her crystal with J.D. Bernal's from graphite, as a reference, and the data matched. In the case of hexachlorobenzene, once again demonstrated the molecule to be essentially flat, but her achievement was to determine the parameters using Fourier analysis, a mathematical tool, for the first time for an organic molecule (Lonsdale, 1931). Lonsdale made the calculation by hand, using the tabulated data. In 1931, Lonsdale returned to the Royal Institute and stayed until 1946 occupying Faraday's old room. At first resumed her work with Bragg and after his death in 1942, continued with Henry Dale. During that time, she worked on magnetic anisotropy of crystals. Firstly, on resorcinol (Benzene-1,3-diol)'s magnetic anisotropy, later on the diamagnetic anisotropy of cyanuric trichloride and "Diamagnetic anisotropy of crystals in relation to their molecular structure" as she titles her publication with K.S. Krishnan (Lonsdale & Krishnan, 1936). A succession of articles regarding magnetic anisotropy was published by Lonsdale. In the early 40s, Kathleen was attracted to the variation of atom's vibrations in crystals with temperature, which drove her to the fellowship of the Royal Society in 1945.

In 1949, she was selected as head of the Department of Crystallography and, for the first time, female Professor of chemistry in University College London, where she would remain until her retirement in 1968. Lonsdale continued studying her research fields with her students and broaden them with new areas as solid-state reactions, pharmacological properties, the study of kidney stones or synthetic diamonds. In the 60s, Kathleen focused on medical science and followed this way until her retirement.

Besides her scientific work, Kathleen also developed an activist facet against war. She and her husband became Quakers in 1935. The concept Quaker is coined in a dissident religious community in England, with its origin in Protestant Christian religion. This community is considered to be an historic pacifist church. Lonsdale believed in non-violent resistance, civil disobedience and the ethical use of science knowledge. During World War II, in 1943, Kathleen entered the prison in Holloway Prison for Women for a month because she refused to register for civil defense and to pay the consequent fine. After this experience, she took part actively in reforming the penitentiary system (*Figure 7*) and in the international movement for peace. Some representative works were “Is peace possible?” (Lonsdale, 1957) and “The Christian Life Lived Experimentally” (Lonsdale, 1976), among other books.

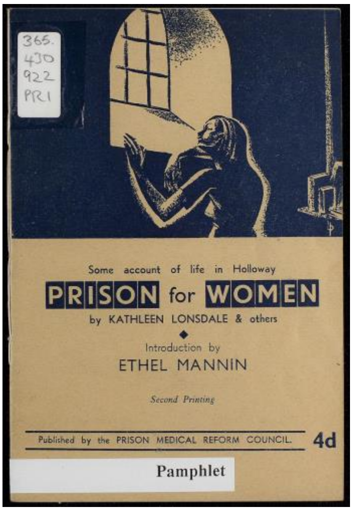

Figure 7: Cover for the book “Some account of the life in Holloway Prison for Women” by Kathleen Lonsdale & others, published in 1943 *(Lonsdale & Page, 1943)*.

(Via Flickr with Public domain)

In her other article "*Women in science: reminiscences and reflections*" (Lonsdale, 1970), she linked the lack of women in power positions of science with the scarcity of female references and role models. Something that nowadays is still commonplace. Lonsdale considered that schools as well as parents had a fundamental role in the encouragement of girls regarding science and technology.

As a part of her scientific and activist recognition, Kathleen was vice-president of the International Union of Crystallography from 1960 to 1966, the first woman president of the British Science Association in 1968, in 1956 was named Dame of The British Empire and many Universities in England such as Gales, Leicester, Manchester, Lancaster, Oxford, Bath, Leeds and Dundee awarded her with honorific titles. Lonsdale continued working in different areas after her professional retirement and passed away in 1971. It is well-known that her influence and example are, partly, the reason why women have been notable in crystallography field (Hodgkin, 1976) (Hudson, 2010).

Most of Kathleen Lonsdale's contributions to chemistry are assembled in the development of X-ray diffraction method of analysis. In the degree, there are several subjects that concern this area. The first one would probably be *Inorganic Chemistry I*, in the intermediate phase of the study plan, introduces crystallin solid structure, Bragg's Law on diffraction and X-ray technique. The *Inorganic Chemistry Laboratory* (ICL) puts into practice the knowledge acquired in theory subjects as the aforementioned. In this laboratory, X-ray is practiced in situ, with monocrystals and powder, besides other characterization techniques and structural determinations. Some optional courses are offered as part of the Chemistry Bachelor (UB). *Crystallography* is one of those, which sets aside half of the program for properties and structure to crystalline matter as well as X-ray fundaments and applications. Another optional subject is *Instrumental Analysis Extension*, which studies each of the X-ray techniques, instrumentalization and sample processing.

4.5. JOSEFA MOLERA MAYO (1921-2011)

The Spanish civil war devastated the country and, with it, all its institutions. Right in post-war period, when the reconstruction was beginning, the chemist Josefa Molera Mayo was starting her career in the discipline. She played a very important role in the development of gas chromatography analytical technique and in the introduction of flash photolysis spectroscopic methods in Spain, activities that had a great impact on the creation of the current research structure in our country.

Molera was born in Navarra in 1921, already in Madrid, she was able, in spite of the post-war situation, to finish her chemistry degree in 1942 and started working as a teaching assistant with Professor Antonio Rius Miró. Meanwhile, she was offered a PhD thesis about electrochemistry in the *Instituto de Quimica Alonso Barba* in CSIC, under Miró's direction. The CSIC director at that moment was professor Casares Gil, who rejected Molera's application of incorporation because there weren't any women in the center yet. It wasn't until Rius was promoted to director when Josefa could start her PhD work in 1946. Her thesis lied in the application of the mercury vein electrode as a possible substitute for mercury drop electrode (Molera & Rius, 1947). The rejection incident recurred when Molera applied for a vacancy in Physical Chemistry Laboratory in University of Oxford in 1950, which, after her tenacity and persistence, accepted her stay.

The chemist came back to Spain in 1951 and implemented the investigation of pyrolysis and oxidation reactions at low temperature of organic compounds in the gas phase, at the Institute of Physical Chemistry and created the Department of Kinetic chemistry, that she would direct until her retirement in 1986. The reaction products were analyzed by IR spectroscopy and radiochemical techniques, such as those using Paneth's ^{212}Pb mirrors for radical detection (Molera, et al., 1958).

The identification and quantification of the products obtained from the oxidation reactions improved with the implementation of gas chromatography (GC). Straightaway, detection of radioisotope ^{14}C was incorporated. The construction of the first gas chromatographer in the department would be possible thanks to Dr. Molera and her closest collaborator, Dr. José Antonio García Domínguez. Therefore, the research directed by Dr. Molera achieved international recognition, especially her studies of inhibition of pyrolysis and formation of cool flames made with fuel-air mixtures, that react chemically at temperatures as low as 120 ^{o}C.

The preparation of new chromatography columns was required as the reactions in the gas phase at temperatures of 150-300 ^{o}C generated a great variety of products. Josefa was deeply interested in chemistry-physics around gas chromatography, it turned into one of her preferred research lines. She made great contributions at a fundamental and applied level, until she became —together with her group— a reference in Spain for the resolution of complex analytical problems, for instance, analysis of alcoholic beverages (Molera, et al., 1978). Some of her contributions were, for example, in the thermochemical study and computer design of mixed phase chromatography, as well as the development of the coupled gas chromatography and mass spectrometry (GC-MS) technique.

In addition, she showed intense institutional activity: in 1972 she created and leaded the Grupo de *Cromatografía y Técnicas Afines de la Real Sociedad Española de Química*, she collaborated in the organization of national chromatography symposia, in Barcelona 1974, and international, in Birmingham 1976. Her contribution to knowledge is collected in 80 publications and 17 doctoral theses and was recognized with numerous distinctions and awards. In September 2011, she passed away in Madrid, at the age of 90.

Despite the unfavorable circumstances of that time, María Josefa Molera will be remembered for developing her scientific career as a woman —with everything that entails— and with the added war and post-war conflict occurring in Spain. She turned into a pioneer in the construction of our actual investigation and research system due to her work on introducing experimental methods and concepts and the great experimental dedication (Acuña & Santiuste, 2013).

Molera's scientific work and achievements contribute significantly to the development of Chemistry in Spain and concretely, to various subjects regarding the Chemistry degree in UB's study plan, most of them in relation to Analytical Chemistry field. At the beginning of the 3rd year, *Instrumental Analysis* classifies and discusses the instrumental techniques enclosed in optical techniques, electroanalytic techniques and chromatographic techniques. The last lesson talks about chromatography basis, classification, efficiency, resolution, and, in case of gas chromatography, instrumentation, stationary phases used and applications. Later in the degree, the *Analytical Chemistry Laboratory (ACL)* puts into practice the knowledge obtained with a gas and liquid chromatography experience, as well as other electroanalytic and spectroscopic determinations. In addition, there are some optional courses that complement the obligatory ones, such as *Separation Techniques*, which addresses the details of gas-chromatography (classification of columns, temperature…).

5. GENDER MAINSTREAMING

5.1. WHY? EQUALITY MIRAGE

We often come across the widespread belief that the inequality between both sexes is overcome in education. This mirage nourishes on the good academic performance of the female students, mostly better than males, and the increasing interest and access to traditionally masculinized careers. As an example, data from last year collected by University of Barcelona, reveals that women's presence in the role of students has been growing in the past five years, and currently, the presence expressed in percentage, is above 60%, regarding degree graduates (66%) as well as master graduates (62%) (Universitat de Barcelona, 2020). This indicates a majority of female students, that success on their studies and graduate, even though not all of them continue on master's studies. Another reason to believe gender equality is achieved, is the protection that the education system has in terms of gender. Some examples of legislations at European level are the Directive 2006/54/ec of the European parliament and of the council of 5 July 2006 on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation (The European Parliament and The Council of the European Union , 2006) and European Parliament resolution of 21 May 2008 on women and science (2007/2206(INI)) (The European Parliament, 2008). Together with other type of regulations as manuals, plans, guides, etcetera, lead us to obtain the necessary equitable education, focused on the development of students and their personalities, leaving aside the roles and stereotypes imposed on gender and rejecting all kinds of discrimination.

However, it is dangerous to believe in such a mirage, since these roles are present in professional field. An example of this lies on, again, the UB's 2020 figures. Despite the majority of female students and their successful progression in studies, only the 26% are Professors and 43% Associate Professor. In research projects, a field that concerns Chemistry, only 41% of the principal researchers are women. This data reveals that in power positions women are still relegated, proof of the aliveness of the so-called "glass ceiling", which in gender studies refers to the limitation of promotion of women within organizations. It is a metaphor named as a ceiling, that limits their professional careers. A steeplechase that prevents them from moving forward. It is invisible because there are no established and official laws or social mechanisms that impose an explicit limitation on the career of women, but it actually exists (Burin, 2008). As an add-on besides data, at the lecture room, gender stereotypes usually are present in the form of metaphors, bibliography, examples or vocabulary.

Another current example is materialized in famous Nobel Prize in Chemistry. Up until 2020, 96% of the prizes regarding Chemistry category have been awarded to men (Nobel Media, 2021). In the last ceremony, Emmanuelle Charpentier and Jennifer Doudna won the Nobel Prize in Chemistry, and their recognition, as scientists and authors of their project, was called into question for allegedly ignore the work of a Spanish male scientist. This event has been intensely repeated throughout history with reversed roles, excepting the polemic. When a woman is finally recognized on such a large scale, turns out to happen very often, as a consequence of the imposed roles of gender: men exhibit great security on their work and shows fragility when it is not recognized as it deserves. On the other hand, women are taught to give (our love, work, patience), accept (prohibition, denial), even reject the merits awarded to us, believing ourselves less valid, a common feeling called The Syndrome of the Impostor.

Therefore, the “Equality mirage” paradox is stablished: women are more and better students, but power positions are still reserved to men. Is vital to introduce gender perspective actively in universities to make researchers and professors, as well as students, aware of other scientific realities besides heterosexual white men’s, and make scientists and future scientists wise to stop the erasure and invisibility on women in history and normalize and encourage the current presence of women in relevant positions in science.

5.2. HOW? INCLUSION IN PRACTICE

5.2.1. General Considerations

To include actively gender perspective in university lectures is primarily important in traditionally masculinized degrees where, due to the apparently objective and neutral nature of the subjects taught, it seems difficult to include a gender-sensitive vision. Some general considerations regarding Chemistry Bachelor, applicable in other fields and Degrees though, are listed below in three principal groups of objectives: actions to make visible female scientists’ work, actions to raise awareness within students in order to eradicate stereotypes and actions to apply reflections and knowledge directly:

Visibility

- At class level: Incorporation of female scientists' contributions to the study plan of the referred subject (for example as an introduction, in the bibliography, as an activity: examples, work in groups, oral presentation, current news…).
- Visibility of discrimination based on gender (in the past and nowadays).
- Cite the full name, not only the initials to favor making female scientists more visible and avoid confusions.
- At faculty level: Suggest concrete actions aimed at making pioneering and current female scientists visible as hallway decoration, exhibitions, campaigns, hosting talks and conferences given by women.
- Social networks used to publish references or contributions of scientist women.
- Include a "Scientific women" open day at the faculty.
- Include a new subject on Gender perspective focused on the degree.

Consciousness

- Reflective practice on non-sexist language.
- Reflection on the biases in the history of science and today, in an intersectional way (racial awareness).
- Use of articles and social experiments as support, for example the Matilda effect. Introduce the concept of gender perspective through role-playing games, role-inversion activities, theatricalization…
- Question the privileges owned by men and the power relations between men and women that derive from them.
- Encourage students' sense of belonging and self-efficacy. Decrease competition and emphasize collaboration.
- Include equality competencies in the teaching plan.
- Raise awareness on the good use of social networks and internet jokes that reinforce gender stereotypes.
- Teach a non-heteropatriarchal vision of the future profession of the degree.
- Work on professional expectative and the differences between male and female students.

<u>Implementation</u>

- Give the floor equally. Avoid interruption between students. Manage classroom in order to create a safe and motivating space (for example wait until several hands are raised).
- Use of inclusive language. Avoid stereotyped images, metaphors, examples or jokes.
- Supervision of the assigned roles in teamwork (female students tend to organize avoid conflicts, arrange dates…), specially to the equal use of spaces in laboratories (for example, implement rotation in computers or instruments) and equal distribution of tasks.
- Promotion of cooperative work in heterogeneous groups.
- Identify exams with ID number in order to avoid sexist corrections. Avoid stereotypically masculine questions (actions, metaphors) to promote identification in both genders and avoid test exams as women have shown to be more dubious and test penalizes doubt.
- Ensure a fair evaluation among students in case of inter-evaluation of works.
- Implement optative subjects in gender perspective.
- Highlight the difficulty of a subject to avoid frustration on female students.
- Normalize stereotypically feminized actions and behaviors using parallelisms and examples with the lesson.

References (Estradé, 2021), (Iglesias, 2018), (Riveros, 2016).

5.2.2. Activity examples

The objective of this section is not to redefine the study plan or change the degree's structure, just to include these previously selected women clearly and actively in some of the subjects where their knowledge contributes. So, through the selection and the study of their contributions, they have been included in some Chemistry subjects.

Currently, the degree is divided in three phases: the initial phase, which is composed of the basic training subjects, the intermediate phase, that includes the compulsory and the laboratory subjects, and the final phase, which addresses optional courses and the Final Degree Project. The following scheme (Table *1*) shows the distribution of the subjects across the degree in different colors, according to obligatory subjects (blue), laboratory subjects (green) and optative subjects (red).

Initial phase		Intermediate phase					Final phase
Basic Chem. I	Basic Chem. II	**Inorganic Chem. I**	Inorganic Chem. II	**Instrumental Analysis**	Inorganic Chem. III	**Opt.**	**Opt.**
Applied Chem. I	Applied Chem. II	**Physical Chem. I**	Physical Chem. II	Physical Chem. III	**Organic Chem. III**	**Opt.**	**Opt.**
Physics I	Physics II	Analytical Chem.	Organic Chem. I	**Organic Chem. II**	Analytical Chem. Extension	Biochem.	**Project mgmt.**
Maths I	Maths II	Chemical Engineering	**Quality and prevention**	Documentation	**AC Lab.**	IC Lab.	
			ACB Lab.	ICB Lab.			FDP
Biology	I.T. Resources	Materials Science	**PCB Lab.**	OCB Lab.	**PC Lab.**	**OC Lab.**	

Table 1: distribution of subjects in the degree. The subjects with a proposed activity are in bold.

For the purpose of including gender perspective in the degree curriculum, a selection of the contributions to obligatory subjects in the degree has been made, based on the four women previously developed: Agnes Pockels, Alice Augusta Ball, Kathleen Lonsdale and Josefa Molera Mayo. Each of them, contribute in a different way to the discipline and to different subjects in the study plan. According to that, some concrete examples, apart from the general considerations, of activities, practices or works are proposed in relation to their main contribution, in the form of a table (Table 2) below.

Scientist	Subject and semester	Main contribution	Activity example
Agnes Pockels	Physical Chemistry I (3rd semester)	Surface tension, layers, capillarity.	Normalization of actions stereotypically feminized of daily life (as wash the dishes) in relation with science: execution of a little surface tension practice at home kitchen with soap and preparation of a debate, presentation or teamwork around Pockels' research.
Alice Augusta Ball	Organic chemistry II (5th semester) Organic Chemistry III (7th semester) Organic Chemistry Laboratory (7th semester) Project management (8th semester)	Leprosy treatment injection.	As there is no direct relation with the subjects, Ball's contribution can be a motivating example. It can be included as a remark at class, a reference at Organic laboratory when any of her procedures are carried out or as an entrepreneurial example.
Kathleen Lonsdale	Inorganic Chemistry I (3rd semester)	Structure of crystals, Bragg's Law, X-Ray diffraction theory.	An analysis of X-Ray laboratories photos: how is the idea of a scientist represented in this area? Design an application of X-Ray technique gender sensible, for instance: mammogram, airport controls, metal detection, quality control… as a work or presentation and posterior debate.
Josefa Molera Mayo	Instrumental Analysis (5th semester)	Chromatography techniques theory.	Design an application of GC technique gender sensible, for instance: measurement of alcohol in blood (differences in body fats, enzymes alcohol-dehydrogenases, contraceptive consumption…), active principal quantity in drugs, as a work or presentation and posterior debate.
	Analytical Chemistry Laboratory (6th semester)	Gas chromatography application.	Prepare a complementary practice in which students can observe the variation of alcohol levels in blood between genders, with blind samples simulating blood with water and alcohol and using GC to quantify the concentration. Then a comparison with the actual alcoholic rate for women and men can be made to motivate a final reflection.

Table 2: activity examples to include gender perspective in various subjects in the Degree.

In order to further develop the proposal of this work and illustrate how such initiatives may be implemented in a higher education curriculum, three examples are described below, with the possibility, if necessary, to extrapolate the ideas to other example activities. The selected examples comprise magistral lecture as well as laboratory environments: on the one hand, the design of an application gender sensible of X-Ray technique, which can be performed around different techniques and subjects, such as GC in the case of Instrumental Analysis or X-Ray technique in Inorganic Chemistry I. On the other hand, it is proposed an extension to complement Basic Physical Chemistry Laboratory as well as Physical Chemistry Laboratory, the reproduction of Agnes Pockels' device: The Pockels trough. As a third option, it is included laboratory hazard prevention with gender perspective, a group activity that can be added in any of the obligatory laboratories during the degree (not included in Table 2). Objectives and guidelines on these three examples are detailed below.

5.2.2.1. Design of an application of X-ray technique with gender perspective

a) Subject

Inorganic Chemistry I, Crystallography (optative subject), Instrumental Analysis Extension (optative subject).

b) Objectives

- Describe the current reality in terms of diseases or danger derived from the androcentric vision that permeates science and its applications, as a result of gender stereotypes, for example, the assumption of unnecessary risks by women and little interest in improving or preventing those risks.
- Raise awareness of sexual harassment and structural violence against women that expresses transversely in daily life, infantilization, trivialization of women's needs, men's superiority behavior on women, reducing the importance of traditionally feminized causes, undervaluing our complaints...
- Propose alternatives in accordance with equality, analyzing the difficulties and inequalities in the different areas that are treated, in this case the applications of the X-Ray technique.

- Locate androcentrism in the field of science and its applications and deconstruct it through examples.
- Encourage creativity and community service, learning to work on real needs of the environment in order to improve it.

c) Material

Computer, internet access, pen and paper if needed.

d) Guideline

After giving the X-Ray lesson, a group work on gender perspective will be proposed, linking with the end of the treated topic.

Introduction to the work

It can be done by briefly reviewing Kathleen Lonsdale's biography, in case it was not mentioned during the lesson, and introducing the concept of "gender perspective". It is a good practice to emphasize the creative part in the work and play down the technical and scientific part, as it will be evaluated in other ways during the course of the subject. It is important to highlight that, as we deal with the gender perspective, we must also take into account other oppressed groups such as disabled, racialized and belonging to the LGBTIQ + collective and recommend adding them in the conclusion of the work.

Formation of groups

Groups should be formed by 4 or 5 members, obligatorily gender heterogeneous, where the tasks assumed in the group will be noted in order to avoid a stereotyped distribution. This task distribution should be mentioned at the oral presentation.

Development

The main idea is to list some applications of X-Ray technique learned in class or found by own research, briefly analyze one of them in relation to gender, and propose a solution, or a new application, designed to be accessible and sensitive to all collectives. With the proposed application, make an oral presentation to expound the idea in groups and generate a small debate around each work. It is recommendable for the students to conduct the research of information in English, as the number of results is greater. Consult and include a checklist (for example the Yellow Window check list that can be found in https://www.yellowwindow.com/genderinresearch) arranged to fit the concrete issue in each group, in order to ensure the integration of gender aspects in the design or application. A checklist example for this activity is suggested in Appendix 1.

Debate

In the context of the group's work that is being discussed, a question is set out and the moderator (usually the teacher), gives the students a turn to speak in an orderly manner, using the whiteboard as support to write down the key ideas if necessary. It is important to give the floor fairly and avoid interruptions between students.

Evaluation

An interesting evaluation is the inter-evaluation and self-evaluation among students, which evaluate other aspects that influence in comprehension of the concepts as teamwork or oral expression, as well as theoretical concepts. An example of an evaluation rubric for an oral presentation is suggested in Appendix 2.

Estimated time

It will depend on the number of students who participate. For the introduction of the work after the lesson, 15 minutes maximum can be estimated. In the case of the oral presentations, taking as an example a total of 4 groups, a class of 50 minutes can be estimated.

Practical examples

X-ray diffraction is a technique used on the development and discovery of new specific pharmaceutical drugs, contributing to the inclusion of gender perspective analyzing compounds. Some examples are male contraceptives, specific drugs for PMS (Premenstrual Syndrome), development of specific drugs for endometriosis… Another example is the use of X-Ray diffraction technique in quality controls by specially paying attention to the analysis of compounds in make-up, cosmetics, hair dyes, treatments... developing less aggressive cosmetics as these are traditionally feminine products and research is still limited.

In airport security control: although this practice is almost obsolete, it is a good example. Pregnant women have potential risk and women are more affected than men. Alternative: Millimeter wave scanner. In medicine: exposure to mammograms or general radiographs entails more risk in women than men. Some alternatives are a better diagnosis, which only require radiography in specific cases, allocate more services and money to gender sensible research or ultrasound diagnosis (no ionizing radiation) (Moore, 2020).

e) Key aspects

- Identify the positioning among male and female clients of the chosen service or application in terms of security measures, prevention, study, etcetera, and link it to gender stereotypes and roles.
- Recognize the relationship between gender stereotypes, discriminatory situations, sexist behaviors ... with the access and use of the service or application in women and men.
- It is important to emphasize that the main purpose of the activity is the inclusion of gender perspective in this specific environment, not to evaluate the viability of the design or the scientific part, as long as scientific criterion is respected.

f) Common mistakes

- Consider all risks, diseases, difficulties or needs equal for the entire population, valuing a single profile (androcentric view) is a mistake. The consequence is not understanding reality in its entirety and hampers solutions and improvements for society.
- It is common to take as biological, necessary and unavoidable, certain behaviors that are actually sociocultural conventions, modifiable regardless of gender.
- It is also common to assess the same situation differently according to the level at which it affects men (it is considered more important, more necessary, more deserving, better paid ...).
- Avoid interested adaptation to the existing reality (“is all there is”, “you must adapt”, “you must fit in”). As a consequence, gender prejudices and stereotypes are perpetuated.

5.2.2.2. Gender sensible risk prevention at the Laboratory

a) Subject

Organic Chemistry Laboratory, Inorganic Chemistry Laboratory, Analytical Chemistry Laboratory, Physical Chemistry Laboratory, Quality and Prevention.

b) Objectives

- The main objective is to identify and analyze the concrete aspects about security and prevention in chemistry laboratories directly related to male or female condition: either physical or stereotypical differences. For instance, the acceptance of more dangerous tasks or unnecessary risks by men because of the traditional male role model, competitiveness, put traditionally feminized tasks aside…
- Pay attention to stereotyped actions and environment of the laboratory besides hazard prevention. For example, value as a risk harassment or sexist vocabulary use, as laboratories are spaces which are shared during several hours a day during several weeks.
- Raise awareness within the students about the importance of gender stereotypes and labor: it can lead to a less quality and efficient work.
- Analysis of how female students' claims and needs are often belittled or trivialized and the way it affects to their health in the laboratory environment, as a consequence of the androcentric vision.

c) Material

It is only needed a guideline for the professor with the main ideas and examples detailed to expound to the students and a computer, printer, colored markers, scissors and glue to prepare the exhibition mural.

d) Guideline

The professor, right before starting the Laboratory subject, should explain about hazards, accident prevention and security in the laboratory. It is a good moment to introduce the activity, as it is related to the security in the lab. The task addresses gender sensible hazards and actions by preparing a mural, with an overview of the ideas that students gather during their lab shift, which may be hanged afterwards in the laboratory or hallways.

Introduction to the work

Like an introduction to the matter, it is good practice to ask the students to simply read about what gender perspective is and how can it be included in the laboratory environment. They can think of some examples, in an informal way, on how to incorporate it in the laboratory they are about to start.

Development

Once the theme is introduced, a discussion between students and professor is induced to share different examples and ideas. If some important examples are missing, the professor should bring them on and add them to the other ideas. During the discussion, a little debate may be created, as a result of different opinions and concepts. In this case, it is important that the professor act as a mediator or moderator prevents interruption between students. As female students are the ones suffering from these differences and disadvantages, it is good practice to ask them specifically what they need or are missing during the debate, in that way, the participation of female students is encouraged too.

After that small debate, students may start their work. During their shift, an empty mural may be filled up with the ideas or experiences which students come up day after day. At the end of the shift, a group reading can be performed to encapsulate the main ideas.

Evaluation

As this activity has a very ludic character, evaluation as such may not be needed.

Practical examples

- Harassment hazard.
- Unbalanced distribution of tasks among classmates. Female students tend to clean the laboratory material, take notes, etcetera, unlike their male classmates, that tend to do the data processing, organization of the practice, handles the instrument…
- Androcentric organization of the "standard" laboratory: Height of the instruments or reagents, security images with male figures, force required for some actions…
- Differences on the limit of exposure to dangerous substances and cumulative effects of exposure to chemicals (man-based studies). For example: exposure to some

chlorinated solvents (Welp, et al., 1998), aromatic hydrocarbon solvents and ionizing radiation are linked to breast cancer (Weiderpass, et al., 1999), cadmium is linked to osteoporosis (Youness, et al., 2012).

- Biological differences, which are always present, such as strong hormonal processes, menstruation pain, etcetera, may require special attention considering the length of shifts in laboratories and physical as well as mental fatigue that imply. These also involve quotidian use of medications, such as PMS drugs or anti-inflammatory drugs, which can produce dizziness, fatigue, headache, stomach cramps…
- Wearing make-up and facial cosmetics can produce some interactions with laboratory environment.

e) Key aspects

- Learn how to analyze and take into account during the stay in the laboratory, the differences in accidents, risks and safety protocols between men and women and the relation to the stereotypes and physical conditions that differentiate genders.
- Identify and propose, as far as possible, some solutions to these risks and security differences and implement them during the shift in the laboratory.
- Pay attention to the positioning of female and male classmates facing with safety and prevention protocols and their design. Do they respond to the expected behavior in each gender role?

f) Common mistakes

- It is a tempting mistake to consider all accidents equally together and not disperse them by gender, claiming that “an accident is an accident, regardless of gender”. This implies erasing gender perspective and turn the consequences of gender roles into invisible, thus hindering possible solutions.
- As a consequence of these roles, it is also common to think that male students are more likely to have accidents performing the same task than a female classmate, since they develop the most dangerous parts and take more risks.

5.2.2.3. Reproduction of Agnes Pockels' trough experiment

a) Subject

Basic Physical Chemistry Laboratory (BPCL), Physical Chemistry Laboratory (PCL).

b) Objectives

- To complete the knowledge on surface tension by means of other method to obtain it.
- Develop creativity to manage the Pockels' trough set up.
- Normalize and make visible scientist women's presence in the examples and references used in the experiments.

c) Guideline

This experiment is intended to be an add-on to other practices already in operation, as it is relatively simple and fast to do. For instance, in BPCL it can be incorporated into practice P6.1 that addresses Critical Micelle Concentration (CMC) and its determination besides surface tension. In PCL both in practices D2 or F2 where the first also deals with CMC determination and the second with surface tension determination.

The main objective is to introduce Agnes Pockels through her work on surface tension and monolayers. She designed the Pockels' trough, a device by which, the force and area needed to calculate surface tension were obtained. The small practice that is suggested intends to reproduce this apparatus and the Pockels calculation method.

Introduction of the experiment

In the students' text-guide, besides the theoretical explanation, it can be added a short summary of Pockels' biography and her work, making known her figure and introducing the idea of the practice. The intention is to observe the variation of surface area when surfactant's concentration is modified (for example, using three concentrations) and determine the surface tension varying the surface area.

<u>Development</u>

The Pockels trough is a device by which it is possible to determine the surface tension in an inaccurate way, but it can provide us an idea of how it varies depending on area and surfactant's concentration. This device consists of a rectangular tray, ideally made of a hydrophobic material as Teflon, where water is poured, a movable Teflon bridge (it can be made of aluminum foil if necessary), a ruler, to monitor the area, and a scale or a dynamometer, capable of measuring mN, connected to a light small ring (approximately 10-20 mm diameter) made of wire. A scheme of the device is shown below (Figure 8). This scheme is not drawn on real scale. It is recommendable to take heed of the area occupied by a molecule of surfactant, for example, in the case of using a fatty acid with a hydrocarbon chain of 16 carbon atoms, it is approximately 20 Å^2.

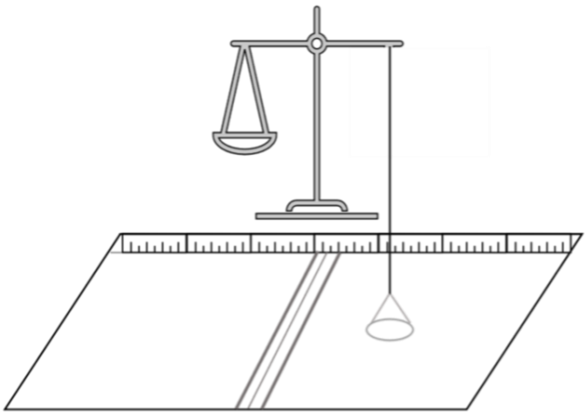

Figure 8: Pockels trough device reproduction scheme.

The experiment is divided in two parts. A first one, in which students observe how, after adding the surfactant on one of the sides of the tray, the area is readjusted; and a second one, in which students measure, at a fixed concentration of surfactant, surface tension in different areas.

1st Part

The procedure begins by placing water in the tray. Once the water is placed, we fix the ruler along the rectangle and the bridge in the middle of the tray on the water, in such a way that it floats and allows movement. After adding the surfactant on one of the sides of the tray, from less to more concentration (for example, with three concentrations), the movement of the aluminum bridge is observed. As surface tension is inversely proportional to surface area according to Equation 1, at the moment surface tension is decreased, the surface increases seeking stability again.

$$\gamma\ [J/m^2] = \frac{W}{S} \quad \text{Equation 1}$$

2nd Part

Surfactant's concentration remains constant, and area is changed each time. In order to measure the different areas, a ruler is placed in the length of the tray. Once the first area chosen is fixed, using a dynamometer or balance, it is measured the force or mass needed to raise the wire ring and detach it from the surface. Mass or force is noted down.

The procedure is repeated with the other areas. The tendency observed is the decreasing of surface tension in small areas as the concentration is higher and the increase of surface tension in larger areas as the concentration is lower, until a maximum, when a monolayer is formed, and surface tension becomes constant independently of the area.

Surface tension is determined using the Force obtained directly by means of the dynamometer or calculated by way of the mass Equation 2, and the length l corresponds to the wire ring's perimeter, as indicated in Equation 3. In case of water, it is expected a surface tension of 72,8 mN/m.

$$F[N] = m \cdot g \quad \text{Equation 2}$$

$$\gamma \left[\frac{N}{m}\right] = \frac{F}{l} \quad \text{Equation 3}$$

To complement the experiment, creativity and chemical criteria can be developed by providing only the calculation formula and the material for the apparatus, allowing the students to discover the set up. This will also help to understand the complexity of such an experiment in Pockels' context.

Evaluation

As this experiment is part of a practice, it should be evaluated all in all.

d) Key aspects

- Part 1: Understand why the surface area increases as the surfactant is concentrated.
- Part 2: Understand why surface tension increases with area and why it turns constant.
- Value Pockels' effort and dedication to science and to the experiment taking into account the few resources that she had (not having access to a laboratory, scarce scientific resources obtained through her brother...).

5.2.2.4. Alternative dynamics

As an add-on, some extra activities are collected briefly to implement these concepts in a more transversal way, out of class context. These may be conducted in a relaxed atmosphere, for instance before or after a conference which addresses the issue, maybe in the "Women in science" day or using lecture time if the course syllabus schedule and conditions allow it.

- "…is needed!": This quick activity bases on the analysis of offers of employment in laboratories, companies, research groups, etcetera, with the main purpose of helping the students and teachers realize how normalized is male vision and the importance of the pertinence feeling.
- "Privilege walk": An activity to carry out in a spacious place as the students or teachers may be in a row. Yes-No questions are asked, and a step forward is taken if you feel in agreement. At the end, privilege tendency is shown with the differences between rows, enticing a debate. Some examples of questions are: "I you always feel safe walking alone at night, take one step forward", "if you usually don't feel interrupted, take one step forward", "if you feel good about how people who resemble you are portrayed by the media, take one step forward", etcetera.

6. CONCLUSIONS

The elaboration of this report brings about various conclusions. On the one hand, the fact that a work of these nature, with all that implies, was proposed and having the opportunity to carry it out as a final degree project demonstrates a great advance and a very positive and motivating cohesion of responsibilities between university's management, faculty and students. On the other hand, it is also a symptom of the enormous work that remains to be done and the delay that means being still in development in terms of gender perspective inclusion in our Chemistry classrooms, a delay which is detected daily as students.

A reflection fruit of this work is a paradox, the illusion or mirage that a change has occurred, and it is no longer necessary to work on gender awareness in universities, since classrooms are full of female students. But the reality is that women continue to suffer the effects of the patriarchal system established, which seeks the perpetuation of gender stereotypes and submits society to androcentrism: oppressed under a single umbrella from which is impossible to get out of, an only perspective from which the world observes, that of man. Science doesn't get rid of it, as it has traditionally been a very masculinized field. Through a brief review of history, I have been able to get to know pioneers of some of the most important areas in Chemistry, names that I had never heard of and whose scientific journeys have been milestones in our discipline. I have set up new references to look at and share with the women around me.

As a means to normalize female scientific pioneers, professors and power positions, referents must be actively included in the teaching plans of Chemistry. Scientific women must be given the space deserved and earned, which they have had to work on, with numerous obstacles, throughout history. This final degree project intends to be another step towards achieving recognition, inclusion, true equality and a more diverse, and consequently, efficient Science.

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8. ACRONYMS

STEM: Science, Technology, Engineering and Mathematics.

AQU: Agència per a la Qualitat del Sistema Universitari de Catalunya.

UB: Universitat de Barcelona.

A.D.: Anno Domini (after Christ).

B.C.: Before Christ.

DNA: Deoxyribonucleic acid.

CSIC: Consejo Superior de Investigaciones Científicas.

FDP: Final Degree Project.

Opt.: Optative course.

AC(B)L: Analytical Chemistry (Basic) Laboratory.

PC(B)L: Physical Chemistry (Basic) Laboratory.

IC(B)L: Inorganic Chemistry (Basic) Laboratory.

OC(B)L: Organic Chemistry (Basic) Laboratory.

LGBTIQ+: Lesbian, Gay, Bisexual, Transgender, Intersexual, Queer collective.

PMS: Premenstrual Syndrome.

APPENDICES

APPENDIX 1: GENDER SENSIBLE CHECKLIST EXAMPLE

Consists of crossing the square if the answer to the suggested question is yes. In this way, at the end, students can review the pending aspects and enrich their work.

Regarding teamwork

- ☐ Is there gender equality in the task distribution: organization, decision-making position, date arranging, conflicts…?
- ☐ Are working conditions suitable for each member of the team (family context, adapted team meeting schedule, safe atmosphere…)?
- ☐ Are the resources needed available for each member of the team (access to material, internet, technologies…)?

Regarding research

- ☐ Has the relevance of gender aspect (outcomes and impacts) to the topic been analyzed?
- ☐ Have you consulted gender sensible resources in the research field?
- ☐ Does the proposed application ensure the investigation of gender differences with the required sensibility?
- ☐ Does the proposed application explain how gender issues are intended to be solved?
- ☐ Does the proposed application comprise other diversities (racial, LGBTIQ+, disabilities…) whenever necessary?

Regarding presentation

- ☐ Is there gender equality in the talking time at the presentation and distribution of transparencies?
- ☐ Do you use images or figures with diverse representation (gender, racial, disability…)?
- ☐ Is the research presented focused on the relevant gender differences?

APPENDIX 2: EVALUATION RUBRIC EXAMPLE

Consists in scoring from 1 to 4, in a table, different aspects of the presentation such as: equitable distribution of time and tasks, creativity, oral expression, use of language and scientific content. It can be delivered at the same time that each presentation ends. It is important to be watchful to the self-evaluations of the female students and the inter-evaluation among them since tend to undervalue their work.

	1	2	3	4
Distribution of time and tasks	Some members participate excessively, and others don't participate.	One member participates excessively or doesn't participate.	Some parts are time unbalanced.	Totally balanced distribution.
Creativity	Visual aid with excess of text, lack of color, no images.	Simple visual aid with lack of images or examples. Use of images with non-diverse representation.	Enjoyable visual aid with quality images with diverse representation.	Teamwork use extras as music, performances, mock-ups…
Oral expression	The group shows a lack of preparation and erroneous concepts.	Unfocussed expression or contradictory argumentation.	Correct expression and fluency.	The presentation is entertaining, with fluid expression and coherent argumentation.
Fair use of language	Use of stereotyped expressions or examples.	Doesn't pay attention at inclusive language.	Watches sexist aspects, examples, expressions, metaphors.	Use of formal and inclusive language.
Theoretical concepts	Absence of clarity when technique is explained, mix of concepts, doesn't talk about gender perspective.	Group explains basic concepts but doesn't talk about gender perspective.	Explains theoretical basis and gender concepts to understand the application.	Comprehends all the scientific and gender concepts involved perfectly.