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Chemistry as Building Block for a New Knowledge and Participation

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Abstract. Chemistry has been identified as the central science: it connects the life sciences with the applied ones. In addition, the degree of branching around chemistry also influences social sciences and intersects in areas such as socio-economics and ethics. The knowledge of scientific concepts for non-specialized audiences, through communication and outreach activities, should be considered as a potent social heritage for humankind. An increase in awareness regarding the benefits based on science and trust would advantage the entire society. Herein, the relevance of a novel way to communicate scientific achievements is described: themes like circular economy and sustainable development are tackled to understand the role of chemistry in developing an *ex-novo* culture of knowledge.

Keywords. dissemination, knowledge, participation.

The perception around chemistry is usually felt as though one is observing a black box. However, even if the content of this black box should not be negatively conceived, this black box called *chemistry* is often associated with threats and complexities. Of course, who perceives the black box as above written is not the only "guilty". The role of chemistry as the central science should not only be delivered by specialists, like those who have attended chemistry classes[1], in places such as a high-school or a university, but also through different platforms which are more informal such as blogs, radio, magazines. It is a consequence that everything is heard, seen, smelt, tasted, and touched, involves chemistry. The comprehension of chemistry at some basic level is necessary to understand the world around us. However, with respect to the negative perception of chemistry, a major issue is usually represented by the difficulty of non-scientists to recognize the chemistry in everyday life: food digestion, use of soaps and detergents, pharmaceutical drugs, cooking, etc. which only represents a small section portion of daily chemistry. However, the voyage along the comprehension of chemistry and chemistry-related affairs has deeper roots[2] dating back to the Greek theory of matter (Plato and Democritus, in particular) and the study of alchemy. Which in turn led to the initial steps for empirical understanding. During the lat-

ter part of the 19th and 20th centuries, following the birth of Mendeleev's periodic table of the elements and the firsts atomic theories, chemistry has been associated with enormous possibilities towards life enhancements through its industrial growth.[3] In particular, the large scale and mass production processes of petroleum refinement has delivered feedstocks for fuels, solvents, lubricants, synthetic fibers, plastics, fertilizers, etc. for many other productions. Although the rising of the chemistry within the industry, together with its implementation especially in the 21st century, has led to undiscussed advantages in terms of wellness and possibilities, and two key, but opposing, perspectives should be considered. On the one hand, the positive view is that it reflects the knowledge and products given by chemistry, with major efforts in the advances in well-being over the past centuries with the introduction of smart materials, new vaccines and drugs for incurable diseases, sensors for early diagnosis, and more. On the other, chemistry has inadvertently, but not solely, contributed to a variety of emerging global problems. In this current period, termed ´the Anthropocene Age´, obvious consequences due to human activities has burdened the environment in numerous ways, such as increase in pollution, influencing climate change and over-consumption of natural resources.[4] Unfortunately, it seems that the latter perspective is the most popular and negative connotations are often associated with the word "chemistry" as a consequence of its history. So much so, that it has led to non-chemists experiencing "chemophobia"[5]. However, the forgetfulness of the benefits derived from chemistry should be carefully considered. From a chemist point of view, this trend needs to be inverted. Chemistry should be considered as a partner instead of an enemy; the black box should be converted in a transparent and open box. And to do this, the role of both chemists and non-chemists is of fundamental importance to establish the role of chemistry as an added resource for a new knowledge.

TASK FOR CHEMISTS

The role of specialists needs to be directed towards better comprehension of the matter by identifying and implementing novel solutions to moderate potential crises. In particular, given the current state of the global environment, more sustainable processes for "greener" developments should be prioritized. The central role of chemistry represents the basis for the green development in numerous ways. By adopting new designs and methodologies, many strategies can be focused on providing more greener routes including generation and storage of sustainable forms of energy (solar energy, fuel cells, carbon capture), development of environmentally neutral synthetic methodologies for obtaining safer chemical products, solvents and (bio)catalysts, ensuring the recycle of limited resources and natural products, and the development of accurate analytical methodologies that can allow for real-time and in-process monitoring of hazardous by-products. To this regard, Anastas and Warner introduced the 12 principles of green chemistry in their book "*Green Chemistry, Theory and Practice*" in 1998.[6] Although the principles were outlined with the aim for greener chemical practices, the vision of sustainability within the chemical industries are often perceived as an increase of the costs of production. Where, by following or adhering to these principles, it is projected to be associated with costs > US$ 50 billion by 2020 within the chemical industry.[7]

Along with its centrality, the ethics of chemistry and chemical practices are reflected in different systems including the biosphere, human/animal health, politics and economics. To this regard, it represents the added point towards the growing of responsibility as the code of conduct proposed by the Organization for Prevention of Chemical Warfare (OPCW): a "Hippocratic Oath" for chemists need to be observed and actively driven forward by the major chemistry bodies and rigorously practiced.[8] However, the ethical engagement of chemists needs to be applied even far from the laboratory bench.

A broad communication of scientific achievements represents a crucial tool for making chemistry less distant, less remote and less arcane to lay audience. When chemists write articles on their findings, these are published in specialized journals, and the use of (necessary) jargon make the approach to non-specialists less effective. The majority of chemists do not actively work on communicating their research in ways that are friendly to non-specialists: from a career point of view, both in research and industry, there are no reasons for most research to be broadly communicated, and it is often perceived as a loss of time.[9] In addition, scientists doing public speaking are often considered to have lost their way as to what is really important. Of course, chemistry is a complex and broad field, that cannot be communicated in its entirety, and great efforts are always requested to make the communication charming. To eradicate the "chemophobia" feeling, the role of chemists should be focused on the adoption of brand-new communication strategies. Nowadays, contemporary platforms such as social media, blogs and videos, open up to a plethora of possibilities for reducing the gap between scientific achievements and society.

TASK FOR NON-CHEMISTS

One of the great challenges for chemists in the 21st century is convincing the general public about the importance of chemistry and transforming the common image of factories pumping out pollution into an concept that shows progress and sustainability at its core. The perfect strategy for communicating the beauty of chemistry, and science in general, has no value if the receiver is not ethically able to participate and understand the information. However, interfacing with specialists through the different existing platforms only represents a step towards the establishment of a new concept of knowledge based on the scientific evidence, rationality and sustainability. For instance, 2019 has been the 150th anniversary and international year of the periodic table of the elements, and great efforts have been devoted to highlight the presence and the role of each element in everyday life. Chemical societies, magazines, roundtables, and radio stations have emphasized many aspects of the periodic table, including its history, global trends and perspectives on science for sustainable development, and the social and economic impacts of this field.[10] Following the same concept, by understanding the role of chemistry and its related processes, the end-users display a major responsibility in decision-making for future (but also current) action regarding tremendous issues that are affecting society. In the current society of consumption, the management of waste represents the latest environmental emergency. In large, it is connected with the manufacturing, exploitation and disposal of products, where approximately 30% of all discarded plastic is not managed or recycled. This does not fit well with a society like ours that largely rely on scarce resources. In this scenario, the urgent need for a shift to a circular model of economy needs competences of chemists for introducing novel ideas of manufacture,[11] the participation of citizens and the close relationship between the parties, i.e. chemists and non-chemists.

Shifting from linear to circular and a regenerative approach represents a turning point for changing the people´s choices of consumption. Novel acquired knowledge for reprocessing of goods and materials are expected to impact social, economic, and environmental fields by generating new, energy efficient, and reducing resource consumption and waste production. Simple actions like the cleaning and repurposing of glass bottles represents a quick and fast way to reuse and recycle glass, for example. Moreover, waste such as organic and/or inorganic can represent the starting point for industries and energy production systems. These actions represent only few examples that are required from a consciously involved citizen: the decrease of water pollution, the reduction of CO_2 emission, and improvements of environment, climate and human health, are just a consequence of a responsible behavior.

CONCLUSION

Nowadays, the word "chemistry" is still associated to something negative. Although, many chemical disasters will not ever be forgotten, chemistry should also be synonymous with progress. The role of chemistry as the central science, and chemists too, represents a current key for a novel sustainable development for preventing the continuous decline of resources. The other key is represented by the citizens, that are asked to ethically collaborate with specialists, through actions in the field of circular economy and recycling. To do so, chemists and non-chemists need to be connected through engagement activities, such as education, where comprehension and awareness of the masses are strictly dependent on these features.

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