



## Chemistry and Society: Peer-Review as Teaching and Evaluation Devices within a Multitude of Subjects

Sérgio P. J. Rodrigues

University of Coimbra, CQC, Department of Chemistry, Portugal

### Abstract

*Chemistry and Society is a compulsory course for the first year of graduation in Chemistry and an optional for the third year of graduation in Biochemistry. In the last six years, it enrolled more than a hundred students in chemistry and the same amount of students in biochemistry, with an average of forty students per year. Students choose their themes with some mediation. Then, they present a pitch with their chosen subject as in a scientific meeting. The instructor acts as a chairperson and there are discussions within the class. After these discussions, the students prepare and submit a revision article with a special format (similar to a scientific journal). The articles are distributed among the colleagues that act as anonymous reviewers. After that, the article is corrected by the author, following (or not) the suggestions of the anonymous reviewer, explaining their reasons, and emphasizing the alterations. The third-year students, act as more mature researchers for the younger ones in the presentations. There are some lessons on finding scientific information, reading articles and books, delivering scientific subjects, writing and revising articles, and other relevant subjects. The final marks are based on the presentation, the revision of the article, and the article itself. In the last six years, parallel to the obvious subjects of sustainability, green chemistry, polymers in society, chemistry and literature, cinema, and various types of arts, chemistry in the war, new materials and drugs, and chemistry in the kitchen, we had some disruptive subjects as the chemistry of hate, religious rituals, homeopathy, and others. All these subjects are treated scientifically, based on evidence, critical analysis of existing peer-reviewed articles, and the revision of the articles. Also, all this fitted easily when the classes were online. The articles and revisions are submitted in specialized platforms by the University of Coimbra, which sends them to plagiarism software automatically. The exchange of articles and revisions is made by the instructor that acts as an editor. The results are very good in terms of marks and evaluation by the students.*

Keywords: *Soft-skills, Chemical awareness, Writing and analyzing scientific documents.*

### 1. Introduction

The importance of chemistry in society is non-questionable (e.g. [1-5]) but most of the time the general public judge it as abstract or difficult. The Royal Society of Chemistry has made a study [6] showing that misconceptions are due to chemists. Others think that chemophobia is real, but not to be contradicted in the usual form but by carefully analyzing the human deeds [7].

Chemistry and Society is a compulsory course for the first year of graduation in Chemistry and an optional for the third year of graduation in Biochemistry. In the last six years, it enrolled more than two hundred students from chemistry and biochemistry, with an average of forty students per year. This year it has 58 students (27 from chemistry and 31 from biochemistry).

### 2. Methods

After some discussion, students choose their subjects. Parallel to the obvious subjects of sustainability, green chemistry, polymers, chemistry and literature, cinema, and various types of arts, chemistry in the war, new materials and drugs, chemistry in the kitchen, Forensic chemistry, and chemistry in the outer space, they chose some disruptive subjects as the chemistry of hate (in opposite to chemistry of love and happiness), specific religious rituals and drugs, homeopathy, human spontaneous combustion, and others.

Some subjects reflect personal experiences of the students, others a genuine want to know better, but others are suggested by general books (e.g. [2-5]) shown to the students or by presentations done by the instructor. A few subjects are somehow imposed (for students that do not choose one) or changed to others as students or the instructor judge them too banal or difficult. We must say that first-year students have some general ideas but lacks (of course) lots of knowledge about chemical activity and subjects, thus choosing utility or mediatic subjects. This is one of the roles of the instructor and the



mediation is to show the hidden subjects to the final results. On the other side, third-year biochemistry students have a more “biochemical” mind, some of them are making their scientific stages, and tend to choose more specific subjects, some related to their scientific stages. Again, the role of the instructor is to guide the students.

The subjects chosen by the students were collected in the titles found in Table 1. Some are repeated or are similar and are not presented.

Table 1: Subjects that are chosen by students.

|  |  |
|--|--|
| Chemistry and food                       | Molecular gastronomy and colloids, myths, diets, food preservatives, additives, pesticides in food, polyphenols, beer, pepper, piments, chocolate, coffee, milk, sweets, stevia, fast-food, natural toxicants.   |
| Chemistry and medicine                   | Fighting fungi and bacteria, tobacco, anesthetics and pain, homeopathy and naturopathy, extreme conditions for human life, multiple sclerosis treatments, cortisone and steroids, caffeine, radiochemistry and radio drugs, benzodiazepines, medicinal THC, nutrition, phthalates in the environment, vitamins, chemotherapy, pill, menstrual products, palliative care, green chemistry applied to drugs, Alzheimer’s disease, tooth and dental treatments, depression, metals and metallic complexes, opioids in therapy, nanoparticles in medicine, cannabinoids in epilepsy, photodynamic therapy, diabetes.   |
| Chemistry and energy                     | Chemistry of combustibles, bio-combustibles, biogas, ethanol, hydrogen, oil products, solar energy, nuclear fusion, nuclear plants.  |
| Chemistry in the boudoir                 | Beauty, cosmetics, tattoos, makeup, baton, soap, hair treatment, dental hygiene, perfumes, detergents, essential oils, foam in hygienic products.  |
| Forensic chemistry                       | Chemistry in forensic research, classical poisons: real and fictitious, old and modern poisons, natural and artificial poisons, explosives, the chemistry of dead, vitriol crimes.   |
| Other technological and utility subjects | Optical fibers, carbon nanotubes, treatment and quality of waters, pigments and inks for houses, solar protectors, ammonia in agriculture, pigments and dyes, asbestos, paper, the substitution of CFC, sonochemistry, fireworks and green alternatives, swimming pools, plastics, ozonolysis, 3D printing, flame suppressors, photochemical applications, organic solar cells, green and biodegradable plastics, mines and contamination, anti-fire materials, remotion of nitrogen from waters, protection masks, glass industry, money, civil construction, the end of the chemical war, chemical weapons: inactivation and antidotes.  |
| Chemistry explaining the world           | Chemistry of emotions (love and hate), transgenics, entropy, vision, stress, allergies and intolerances, the effect of the increase of carbon dioxide, sleeping and dreaming, head transplant, the chemistry of evolution, epigenetics, color of the skin, hardness of materials, global warming, CRISPR Cas9, vanishing of coral reefs, fireflies, dopamine, virus: chemistry and biochemistry, supramolecular chemistry, oxidative stress and antioxidants, mineralization of waters, Orion Galaxy, beginning of the universe, space exploration.  |
| Local and very specific subjects         | Production of saccharin beet in the Azores, Christianized ecstatic rituals, chemical popularization for hospitalized children, adrenoleukodystrophy in the film “Lorenzo oil”, imaginary substances with impossible properties in the literature, laboratory animal sacrifice, dimethyltryptamine.   |
| General and historical subjects          | Chemistry and economy and politics, music in teaching chemistry, chemistry in daily life, agriculture, chemistry and cinema, radiochemistry, material from the past and present, chemistry in Jules Verne, witchcraft and popular wisdom, ethical questions in research, the chemistry of the sea, sports, football, tennis, art preservation, restoration and conservation, green chemistry, sports, Egyptian mummification, plastics and circular economy, the chemistry of learning, benzene, alchemy, radioactive dating, recent findings of chemistry, nuclear chemistry, chemist’s biographies, chromium, patents, water mineralization, chemical pollution, computational chemistry and chemoinformatics, chemical weapons in the two great wars. |



“Chemistry and war” and “chemistry of space exploration” are a class of subjects that are expected to be more chosen, but somehow the students do not choose much these mediatic subjects and their choosing were included in other sets. The approximate timeline can be seen in Table 2.

Table 2: Approximate timeline of activities.

|            |   |
|------------|---|
| Weeks 1-2  | Choosing the subject, learn how to find information, about journals, editors, and authors, and how to write and revise an article   |
| Weeks 3-8  | Five minutes presentations (pitch) of the subjects plus ten minutes discussion Writing the revision articles based on the presentation and discussion   |
| Weeks 9-12 | Writing the revision articles based on the presentation and discussion  |
| Week 13    | Engage in the anonymous peer-review process   |
| Week 14    | Receive the anonymous revision of the written article   |
| Week 15    | Correct the article after the revision (the authors are not obliged to follow the reviewers but it is expected to reflect on their comments and answers accordingly) and responding to the reviewers' comments through the “editor” |

The students present their subjects in a pitch of five minutes. Most of them conform to this schedule, but there are some with more material or do not control the time and use more time. The instructor gives some advice on this, as most of the time people are not allowed to have extra time. We have ten minutes for discussion (even for the ones that use extra time) but there is plenty of time to discuss the subject in classes or by e-mail. After this discussion, where the colleagues are encouraged to participate, the student chooses what to write on the article. Then she or he submit it to a platform where the documents are analyzed automatically for plagiarism. If there are some “red bells” the instructor analyzes the document and gives extra advice to the student. After being submitted, the article is sent to an anonymous referee within the class. The students are advised which is non-ethical to reveal that she or he is the referee. The revision is sent and it is also evaluated. The students have some guidelines on evaluation. Finally, the student receives the revision and acts accordingly, correcting and submitting the final article.

The students are advised that if they find mistakes, they can correct them, and if they are not obliged to act according to the reviewer's advice, but reflect on their words. More, if they do not agree with the review they can say it but politely. They are also informed that the final decision is of the editor, but there are some journals that do not allow discussion. The final mark is based on the presentation, writing and correcting the article, and the revision. There are some studies similar, where the evaluation is based on peer-review [8,9].

Of course, we can have some drawbacks. If students do not do each of the three things normally are not allowed to pass. Also, if some reviewers surpass the time scheduled, the instructor makes the revision itself for the student to have the opportunity of passing to the next phase. But this is very rare.

### 3. Conclusions

The marks are in general very good, there is a genuine enthusiasm of the students, and their evaluation of the course and the instructor is very good. We believe that this course is valuable for developing their soft-skills and through life.

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