ChemPubSoc Europe
DOI: 10.1002/chem.201605259
CHEMISTRY A European Journal
Editorial

# The Ethical and Social Dimensions of Chemistry: Reflections, Considerations, and Clarifications**

Jan Mehlich,*[a] Frank Moser,[c] Brigitte Van Tiggelen,[d, e] Luigi Campanella,[f] and Henning Hopf[b]

**Abstract:** "Ethics in Chemistry" is a huge topic with various viewpoints and arguments on what it actually is and what compliance to ethical guidelines and participation in ethical discourse imply, covering principles of science and research ethics, profession ethics, and technology ethics. Overview and clarity are lost easily. The authors—members of the recently formed EuCheMS working party "Ethics in Chemistry"—present an attempt to collect and sort the ethically relevant aspects and challenges that chemists see themselves confronted with. Based on this list, strategies for ethical action are outlined. On the one hand, there are those issues that are a matter of compliance to existing guidelines and standards. On the other hand, there are those conflicts that arise at the intersection of science, technology and society and that need engaged chemists participating in the larger discourse for sustainability. This Editorial attempts to point out why this is important and what chemists can do in particular.

EuCheMS European Chemical Sciences
WP on Ethics in Chemistry

## 1. Introduction

Science and technology shape our society more than ever, both on a regional and global level. Chemistry, as one of the key sciences, has a significant impact on the development of products and on the availability of substances and materials for any kind of usage. In this way, it contributes to economic growth and wealth in the developed as well as in the developing world. With the rise of constructivism and pragmatism as predominant paradigms in politics, sciences, economy, and other social spheres, the awareness has been raised that progress in science and technology as a social endeavor is controllable, designable, and at all stages debatable.[1] The emergence of *science and technology ethics* and its interdisciplinary discourse that involves its most prominent enactor, the scientist him/herself, is one of the clearly observable phenomena arising from this paradigm.[2] The academic Humboldtian ideal of scientific conduct being *free* and *independent* from any kind of political, economic, and social management/control/regulation is no longer tenable. At the same time, the figure of the man of knowledge devoted to the common good through scientific activities and research, the *Gemeinnütziger Wissenschaftler* (the scientist for the common good) that emerged also at the turn of the 19th century, is more appropriate than ever.[3]

Chemical activity is reflexively connected with worldviews, values, and belief systems that are deeply rooted in society's historical, cultural, and political framework within which it is conducted.[4] It is not difficult to see how chemical progress as a process deeply intertwined with various social spheres influences economy and politics, for example, by enabling new technologies, and by this also society and—to a certain extent—culture, while it is itself shaped by various societal instances and stakeholders (e.g. politics, business, public *Zeitgeist*).[5] The ethical, social, and cultural dimensions of chemistry are manifold, but to date these have been recognised and outlined mostly by the academic communities in the social sciences, humanities, or philosophy (*Applied Ethics*). Both the intellectual contribution of chemistry-related enactors to the reflection of ethical aspects of chemical activity and the recurrent impact on its conduct and methodology is insignificant. This Editorial as a joint production of members of the recently formed EuCheMS working party "Ethics in Chemistry"[6] aims at responding to this situation. This Editorial can be considered as a position paper for chemists written by chemists who are involved in the broader ethics discourse. It seeks to raise awareness for the fact that the *creative science* chemistry is in-

[a] *Dr. J. Mehlich*
*Research Center for Sustainable Energies and Nanotechnologies*
*National Chung Hsing University*
*250 Kuo Kuang Rd., Taichung 402 (Taiwan)*
*E-mail: jan.mehlich@nchu.edu.tw*

[b] *Prof. Dr. H. Hopf*
*Universität Braunschweig (Germany)*

[c] *Dr. F. Moser*
*Secretariat of the Basel, Rotterdam and Stockholm Conventions,*
*United Nations Environment Programme (UNEP) (Switzerland)*

[d] *Dr. B. Van Tiggelen*
*Chemical Heritage Foundation, Philadelphia (USA)*

[e] *Dr. B. Van Tiggelen*
*Mémosciences asbl, Louvain-la-neuve (Belgium)*

[f] *Prof. Dr. L. Campanella*
*Università degli Studi di Roma "La Sapienza" (Italy)*

[**] *The views expressed in this Editorial are not necessarily those of the UNEP.*

herently interwoven with worldviews and value systems, and to illustrate that for chemists the reflection of ethical and social issues of chemistry, the compliance to ethical guidelines of the chemical profession, and an active contribution to its discourse are not a luxury avocation to participate in during spare time, but have positive impact not only for the individual chemist, but for the chemical community and society at large. The question posed by Nieland, whether scientists *need ethics* or whether it is sufficient *to act morally*,[7] is considered herein with specific regard to chemistry.

*Chemistry* is here understood as a multi-stakeholder and cross-sectoral endeavor. For the purpose of this Editorial, chemistry shall include the following:

- Academic sector, with its basic science spreading across the spectrum from material sciences to the life sciences and chemical engineering;
- Chemical industry, including the development, production, marketing, trade, storage, and transportation of chemicals;
- Down- and upstream users, including consumers; and
- Public sector, including national and international bodies tasked with the governance and regulation of chemicals as well as with the enforcement of chemical policies.

Therefore, we prefer the term *chemical activity*, and could use terms like *molecular sciences and technologies* (as communicated by EuCheMS), but we will use *chemistry* in the following sections in order not to make the text unnecessarily complicated. The parlance of *chemists*, then, ranges from practitioners like scientists and engineers to technicians, chemical industrialists, traders, dealers, and regulators. However, despite the importance to keep this variety of stakeholders in mind when reflecting on this topic, this field of different interests, different latitudes and scopes of action, and different expectations on professional and social roles of different stakeholders is much too large to be covered in one article. Therefore, addressed in this Editorial are primarily the chemical enactors in the first sector listed above, at the beginning of the development chain: researchers, scholars, academics, from basic to translational science—mostly covered by the readers of this journal. These are all included when we refer to "chemists" in the following.

In the subsequent sections, we will first highlight those ethically relevant issues of chemistry that have been discussed in the recent decades or that we became aware of in other ways. We will see that the arising issues can be sorted into an *internal* domain that deals with those aspects that are critical within the chemical community and for individual chemists, and an *external* domain that addresses all the questions at the intersection of chemistry and society. Moreover, two kinds of ethical issues can be distinguished that require different treatments in terms of ethical analysis: *Known* and clear cases such as aspects of profession ethics for *good scientific practice* and science and technology ethics for *social implications of chemical activity* on the one hand, and ethical assessment of *new* dilemmas arising from scientific and technological progress on the other hand. With the clarification of those *hot topics* and their classification, we can then proceed to *meta*-ethical reflections on the meaning and usefulness of *ethics in chemistry*, defining the role of the chemist in the discourse and the opportunities and duties of chemists to participate in it. This Editorial shall provide an orientation to chemists for finding conclusions and guidelines upon which to act to help solving ethical and social grievances that go along with chemical activity. It shall neither be regarded as a complete compendium of chemistry-relevant *applied ethics*,[8] nor by any means as a contribution to the *philosophy of chemistry*[9] or the philosophy of science in general. The authors' primary goal is to *build bridges*—between the normative and the empiric, between the professional and the responsible, and between the innovative and the sustainable—and invite the chemical community to participate actively in *Ethics in Chemistry*.

## 2. Two Domains of Ethically Relevant Issues

When brainstorming on the *ethical aspects of chemistry*, probably every chemist can bring in one or more examples in which he or she has encountered questions with an ethical character—one of *right or wrong* or *good or bad*. The list can grow exorbitantly long and needs sorting and classification to keep the overview structured and meaningful. The most obvious aspect for grouping the cases collected by the authors is that of *relevant domain*: some are related to the work of an individual chemist or the performance of the chemical community, others arise from the impact that chemistry has on societal, economic, and environmental spheres. We denote these the *internal* and the *external domain*. Another strategy to characterize the ethically relevant topics is to separate *ethically clear* cases (those in which the normative debate on what is *right* or *wrong* has already resulted in widely accepted conclusions) from those in which the ethical concern arises from on-going progress, from uncertainty, or from new types of conflicts, so much so that the ethical discourse is unsettled and needs professional ethical expertise. The former sorting strategy is used in this section to present the huge variety of *ethical hot topics*, while the latter is discussed in more detail in the next section.

### 2.1. The Internal Domain

#### *Good Scientific Practice*

Scientists, engineers, and researchers perform their activities in a regime characterized by professionalism and responsibility. Therefore, it is important to follow guidelines of good scientific practice and refrain from misconduct—in other words: ensure a high degree of scientific integrity.[10] This means, similar to medical professions for instance, scientists should comply with a professional ethos of scientific conduct. An ethos is a term used for a set of virtues that members of a professional community agree they should follow. What are virtues of scientific conduct? First of all, we may expect intellectual honesty and truthfulness from researchers, making them commit themselves to truth seeking and truth assurance. Another aspect is the often raised call for objectivity and dedicated disinterestedness, which just means that a scientist should have no other interest but the generation of insight and knowledge, and especially no interest in the kind and type of result obtained. The selfless devotion to the ambitious goal of the growth of knowledge should not be blurred by selfish careerism or the interests of any sponsors. Methods for obtaining these ideals are systematized doubt and disciplined self-control. Apart from that, it is justified to expect fairness from scientists concerning their colleagues and competitors. These are virtues for the individual scientists for their daily research work. There are also communal virtues for the scientific community as a whole: Science should be universalistic, that means valid regardless of time, space, and cultural framework. It should not follow individual interests but on the contrary, in each individual action, support and benefit the community of scientists or the social institution science as such—this is called communalism. Also, scientists should always be their own strongest critics, always question their theories and findings, and be the most sceptic about their own achievements.

Some authors remarked that this set of *codes of conduct* for scientists is not *ethical* in the narrow meaning of the word and that a *science ethos* cannot be a valid *universal moral of a scientist*, because it does not affect the *integrity of other entities*. However, the suggested measures are in accordance with moral norms that are valid also in public outside the scientific community. The dimension of a universal moral becomes obvious when exchanging *integrity* by *interest*. Breaking the above-mentioned rules clearly violates the interest of other scientists and their social subsystem. They are made to protect those interests and to guarantee an optimal and fair cooperation of all involved parties.[11]

These virtues describe an ideal. The reality, actually, looks different. According to recent studies, the number of scientists doing *bad science* is tremendously high.[12] What is scientific misconduct? Above all, it is fabrication, falsification, and unauthorised copying (plagiarism) of data and text—the so-called *FFP categories*. Some cases like that of Korean geneticist and biochemist Hwang Woo-Seok,[13] who fabricated an enormous amount of data in order to keep the illusion of the correctness of his revolutionary research alive, are obvious and clear in ethical evaluation.[14] However, there is a very large *grey zone*! When does *manipulation of data* start? Researchers face this situation every day: They repeat an experiment four times. Three times it shows a result they expect, one time it deviates from the expectation. Shall they just ignore that one? Skip it and never mention it again? Or within a series of measurements, one obtained value is far off. Delete that data point? It must not always be the intended manipulation of a device or the direct fabrication of results (inventing data without doing an experiment or study). The bias starts earlier, but can grow into the clearly illegal area. *Trust*—in oneself, one's colleagues, the applied methodologies, experimental setups, the equipment, and the technical devices—and *good will* are non-scientific categories that are subtly pervading all research activity. The sophistication of spectrometers and other imaging devices as technical extensions of our limited senses turns them more and more into black boxes. This convenience bears the danger of a temptation to interpret pictures[15] benevolently and in accordance to the expectation (or the desired finding) rather than with the necessary critical analysis—a perfect example for the impact of the philosophy of science on the ethical conduct of science.[16]

Why would scientists tend to improper conduct of research or even fraud? Many researchers feel a lot of pressure from intense competition within their institute or scientific community, from a funding source, or from expectations by others or by themselves. Certainly, the character or personality of the researcher plays a role, and it is often pride that makes a scientist commit fraud. Many reported cases suggest that—in view of the expected prominent application of (fabricated or falsified) findings and the subsequent fame—the researchers committing fraud must have been fully aware that their misconduct will be uncovered, hinting at pathological behavior that requires therapy and treatment rather than punishment and dismissal from their academic positions. Students are a special case: Diploma, Master, or PhD students feel pressure to achieve a good mark with their thesis, so they feel like they have to obtain good results in their research project that is often limited in time.

Next to the fabrication, falsification, and plagiarism aspects, there are a couple of other forms of immoral science conduct:[17]

### *Publication of Chemical Research*

Grievances in this field, interestingly mostly reported or expressed by scientists themselves, cover aspects of authorship (adding authors to a paper who actually didn't contribute anything to it, like the PI of a PhD student or PostDoc, or honorary authorships), peer reviewing (rejecting papers or grants for reasons of competition, theft of research ideas or results), fairness of *impact factors* as quality indicators and their power over a researcher's career prospects, influence of external stakeholders on the publication of results (for example industrial collaborators with financial interests, publishers, institute directors, etc.), citation practices, and others. Since citation has an impact on priority, ranking, and visibility of researchers, their work and potential future prospects, the act of citing, mis-citing, or not citing has a strong influence on scientific practice and progress.[18]

### *Safety Issues*

Ignoring or violating safety regulations and guidelines for labs and other workplaces and processes (for example transportation and storage) that involve the handling of more or less harmful chemical substances and compounds affects the safety of individual labworkers, that of co-workers and colleagues, as well as the local, regional, and in the worst case global public and environment. The responsibility often, but not always, lies in the hands of individual practitioners or their institutions/corporations. The impact, however, in many cases exceeds the individual range. This creates a special (ethical, but often also legal) duty for chemists to comply with safety regulations.

 

*Education and Mentorship*

This aspect is a specific one for university scholars who, besides doing chemical research, teach students and supervise their master and doctoral theses. Reported conflicts arising from the special situation of mentorship are discrimination, sexual harassment[19] or other cases of an inappropriate exploitation of the imbalanced teacher–student or supervisor–student relationship. However, most ethical dilemmas in chemical education at university occur on a much more subtle level.[20] Ethical challenges emerge during simply setting or marking a thesis. Being *kind* to a poor student has unintended consequences which are neither kind nor ethical. In fact, this *kindness* becomes less innocent when the lecturer's job or promotion depends on a good pass rate. Failing students limit funds available for promotion and cast aspersions on their Professor's teaching abilities. But the upshot is less obvious: the beneficiaries of this easy pass are our future postgraduate students, teachers, academics, attorneys, political leaders, and experts in ethics. What is worse is that brilliant students are neglected or, at least, relatively downgraded. The challenge gets more complicated when the students enter the phase of their own research work: deciding how much assistance to give postgraduate students, estimating the difficulty of their research project, deciding on when and where to publish their work, all these are aspects that require tacit intuition. Whereas the students' interests are clearly their successful graduation, fair treatment (in comparison with others), and a smooth start into their further career (e.g. being provided with the necessary skills, ideally placing a first publication in their field of interest), the PI's major focus is on funding, the management of research group resources, strategically well-timed and well-positioned publications, and a good reputation within and around their institute/faculty. Too high expectations and evaluation standards might scare away students, but when the degree can be obtained too fast and easy the PI risks a decline in credibility. The same factors that impact the current publication and funding practices also play a role at this stage of education: The potential quantity of publications in low-impact journals is the overriding consideration in designing research projects. In other words, the more traditional utility- or curiosity-driven research approach is career-limiting—a luxury that few can afford. Consequently, data collection replaces hypothesis-driven research because training operators instead of educating academics and scientists is more profitable and consumes fewer resources, and results are guaranteed. Responsible for this situation is not primarily the individual scholar, but rather the systemic infrastructure manifested within the global chemical community. Interestingly, it has been shown that the above-mentioned problems occur in almost every country and every cultural realm.[21]

### 2.2. The External Domain

*Chemistry's Specialty: New Chemical Substances*

Chemists impact the world and its societies with the design, fabrication, and distribution of chemical compounds,[22] some times with negative results that affect societies globally.[23] When pointing out chemistry's characteristics in comparison to other sciences, one might find these three: *creativity*, *flexible applicability*, and *inductive knowledge*. Each one is accompanied with ethical and social implications.

Creativity results from the ability to design and synthesize new molecules, or achieve new paths to synthesize useful molecules, for intended and desirable purposes, for example to fight diseases, the hunger of the world, or environmental pollution, but also for the sake of pure knowledge. Because these molecules or synthesis can be put to use, a question of crucial ethical and social dimension is that of patenting such compounds or the proecesses for their synthesis, thus limiting their free use, even if absolutely necessary, for ill patients, for the poorest societies and countries to help their population, especially children. Here, the above-mentioned *conflicts of interest* come into play again: The chemical researcher's interest in career, fame, funding sources, etc., might conflict with the goal to obtain *ethically and socially sound* achievements. This can be the case in several ways, for example in neglecting or ignoring certain research projects (a standard example is research on drugs for third-world diseases that have little potential of commercial profit), or the exaltation of the properties of a new molecule to achieve worldwide fame and success even if the experimental results were not so promising, thus inducing unmotivated hope in people waiting for this new molecule (for example, related to the cure of their illness).

Flexible applicability, here, means the potential of the same *chemical output* (a new substance (class), a synthesis process (e.g. a new catalysis), a technique (e.g. surface patterning), etc.) to be exploited and used by a wide variety of stakeholders, ranging from industry and economy, various applied fields (medicine, engineering, warfare, agriculture, etc.), in both public and private sectors, impacting the society, and the environment to different extents. To find the right equilibrium between support of industrial development, social implications, and environmental impact can be considered a duty of chemical enactors. It also touches aspects of *dual use* and other risk-related issues that are discussed in the next paragraph.

The generation of knowledge in chemical research mostly follows the logic of induction, starting from *results*, challenging them by *making cases* (e.g. designing and conducting experiments) and concluding the underlying *rules*. This is the opposite of deductive knowledge that concludes the *result* by evaluating an observed case in view of a known rule (the case of *bad science* by abduction—in search of cases to confirm hypothetical rules that would explain the observed results—shall be omitted here). Whereas deduction—as long as it is free from logical fallacies—has a high degree of certainty but doesn't produce new knowledge, induction gives access to new insights that can almost never be completely certain (for completeness: abduction gives a *best explanation*, at best). Therefore, continuous resource- and time-consuming investigation and experimentation is required to increase the level of certainty in *chemical knowledge*. Considerations where to set the balance between *knowing enough* and *investing more*, possibly putting workers, researchers, the public and the ecosystem at risk, need careful decision-making and—in some cases—ethical reflection.

### *Risk and Science under Uncertainty*

The debate on the responsibility for implications, risks, and harm as well as benefits, is not solved and might never be. Undoubtedly, chemists are not free from any responsibility. The question is rather: How can it be defined and what does it actually mean for specific cases? The aspect of risk (a wide range of aspects from risk perception to risk assessment, risk identification and evaluation, to risk communication) is the most significant one, especially since the *new science paradigm* of doing *science under uncertainty* (especially in the fields of emerging and converging technologies such as the NBCI group: Nano- and Biotechnologies, Cognitive sciences, Communication and Information technologies),[24] become predominant in science and technology governance and performance. Here, researchers decisions and actions have an impact on the sphere outside of their professional environment and, therefore, charge them with responsibility that requires ethical reflection.[25] A phenomenon that is often seen as an inherent problem is the duality of use of chemical substances. An example is the research on and development of explosives, that the particular researchers promote for applications in mining, construction, and space engineering, while the source of their funding (the military) has the potential benefits as warfare agents in mind. Whether basic and applied researchers are in any way responsible for the applications and exploitations of their research findings, and whether it must be regarded as their ethical duty to ensure the ethical acceptability of the outcome of their research, is still debated heatedly.[26]

*Risk* is not a fixed quantitative entity. Notably, it varies over time. What is believed to have great prospects and benefits on one day might turn out to have devastating effects or cause unacceptable harm the next day. Chemical examples are the insecticide DDT (dichlorodiphenyltrichloroethane) and hydrocarbon polymers (ubiquitous plastic products)—both Nobel prize awarded achievements that now are mostly known for polluting the environment and entering the food chain as an irremovable toxin (DDT), and, respectively, as harm for marine life forms that incorporate the microbeads that plastic in the ocean ends up as.

Uncertainty aspects of scientific and technological progress have been debated and addressed by governance and regulatory instances in the EU and its member states. Variations of *precautionary principles* have been applied to science and technology policy-making.[27] However, many chemists don't know what those actually mean. It is advised that researchers and other practitioners familiarize themselves with common regulatory principles so that they can fully comply with them, and that the training and education of chemists include such issues of science governance and of science ethics in their curriculum.

### *Sustainable Development*

Last but not least, chemistry and its progress is intertwined with and embedded into the development of economy, society, and culture. In the past decades, the term "sustainability" has extensively been exploited to set impacts of science and technology and its governance into a balanced perspective.[28] How "sustainable", then, is chemistry? Can it be improved? What are the particular options of the chemist to support "sustainable development"?

The United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 (Rio "92) was a pioneering international conference that saw a number of groundbreaking outcomes, such as Agenda 21, a blueprint for a global partnership for sustainable development in the 21st century. Moreover, Rio "92 was the birthplace for a series of international environmental agreements in the field of biodiversity, climate change, and desertification. In the chemicals field, the Rio conference gave impetus to the adoption of the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and of the Stockholm Convention on Persistent Organic Pollutants.

Being the most recent international agreements for the management of chemical substances, the underlying values of these conventions embrace contemporary principles in the context of environmental ethics, such as sustainable development, the principle of *common but differentiated responsibilities*,[29] the *polluter pays* principle,[30] and the *precautionary principle*.[31] All these ethical principles have in common that they seek to address the increasing risks that societies nowadays are exposed to. With an inexorable change of paradigm of the society towards the perception of risks,[32] particularly following a series of industrial accidents in the 1970s and 1980s, the broader public is nowadays paying more attention to the fact that chemical production involving hazardous chemicals may be associated with health risks to communities when accidents occur. This holds particularly true since the environment is in fact not so much a luxury of the rich as a necessity of the poor.[33]

In 2015, the international community addressed this changing perception of risk with the adoption of the *2030 Agenda for Sustainable Development* and the *Sustainable Development Goals* (SDGs) at the United Nations Sustainable Development Summit. The environmentally sound management of chemicals and waste affects almost all aspects of development and, therefore, support the implementation of many, if not all SDGs. Achieving the environmentally sound management of chemicals and all wastes throughout their life cycle is a specific target under SDG 12 on *Sustainable Consumption and Production*. It is referred to under SDG 3 on *Good Health and Well-being* and SDG 6 on *Clean Water and Sanitation*. The environmentally sound management of chemicals and waste also supports achieving the goals and targets in other areas, such as food security, health or sustainable cities. Upgrading industrial processes in the chemicals and waste cluster can help to achieve SDG 9 on *Industry, Innovation and Infrastructure*.

Speaking for the *western world* (Europe, North America), in the past four decades, the societal spheres *politics* and *science and technology* have undergone significant shifts of paradigm, from positivistic modernism to constructivist pragmatism, from representative to deliberative democracy, from first-order (choice of objectives, effectiveness, and costs of means–rational decision-making model of politics) to second-order policy discourse (generic values, visions, belief systems—constructivist approach of policy-making). This paved the way for multi-stakeholder approaches of *sustainability*, pro-active science and technology governance tools like *(parliamentary) technology assessment* and interdisciplinary discourse arenas debating *ethical, legal, and social implications* (ELSI) of science and technology. Additionally, a sharpened awareness for the complexity of *systems*, the holistic interconnectedness of elements of such (e.g. social) systems, and the necessity of cooperation between different fields of expertise and competence have significantly increased the efforts to approach science and technology aspects with interdisciplinary assessments. One visible example that many chemists in the EU have probably gotten in touch with in recent years is the fact that every larger research project includes an obligatory ELSI work package in order to implement a more mature analysis of these issues as a basis for EU-wide regulatory governance and policy-making on the one hand, and to facilitate a more democratic governance procedure and incorporate public participation to examine the risk issues arising from science and technology policy innovation on the other hand.[34] Another example is provided by a group of chemists promoting the concept of *One-World Chemistry* that understands chemical activity in the above-mentioned holistic sense as a constructed system.[35] Besides that, active steps have been taken especially in the fields of potential misuse of chemicals, for example *The Hague Ethical Guidelines* for applying the norms of practice of chemistry to support the *chemical weapon convention*.[36]

Chemists have a claimable moral obligation to put into practice the ethical commitments that are inherent to international environmental agreements.[37] The evaluation of the implementation of the above ethical principles in chemicals management also provides valuable input for the much broader discussion on "Chemistry and Ethics" and how the risks emanating from the production and use of chemicals can be better managed. But scientists predominately use scientific methods to assess risks, seldom with a full understanding of the complexities of the natural environment. This is aggravated by the use of simple models and of aggregated data in an attempt to cope with this complexity. Also, the underlying uncertainties or value judgments of the methodologies themselves unfortunately are rarely questioned.[38] For all these reasons, it is highly relevant to consider ethical aspects both as research and educational topics.[39] It is thus the obligation of universities to integrate the intellectual tools needed for sustainability in their curricula, for the younger generations are the custodians of our common future.[40]

Figure 1 summarises all above-mentioned aspects from 2.1 and 2.2. From top to bottom the responsible instance ("who is in charge", from individual enactor to the society as a whole) is depicted, while the horizontal axis illustrates qualitatively the impacted instances, again from individual enactor (left) to societal sphere (right).

## 3. Why "Ethics in Chemistry"?—Meta-ethics of Chemistry

To understand what *ethics* is about we need to look at some definitions. The first and maybe most important one is the linguistic distinction between the English singular term *ethics* that refers to the philosophical discipline and the plural term *ethics* that refers to particular rules and guidelines as a synonym of morals. *Ethics* in philosophy means the *study of what is good and/or right* and has a tradition that dates back to the ancient Greek philosophers in Europe and Confucius, Laozi, and Buddha (amongst others) in Asia (6th century BC). It is useful to distinguish *descriptive ethics* (the study of what certain people or societies believed in certain times), *prescriptive ethics* (the core of ethics, elaborating the normative rules we call

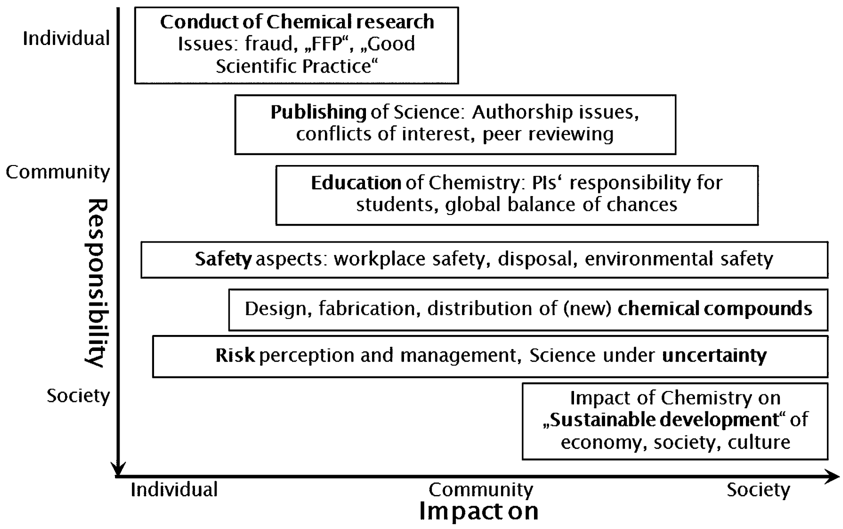


**Figure 1.** Overview of internal and external ethical and social dimensions of chemistry.

morals), and *meta-ethics* (the *ethics of ethics*, reflections on purpose and performance of ethics). In recent years a new boom of ethics could be observed under the umbrella term *applied ethics* (or sometimes *practical ethics*). Most prominent examples in this field are bioethics, medical ethics, research ethics, business ethics, profession ethics, media ethics, and political ethics. A huge amount of books, journal articles, and essays has been published in this field that is understood as a normative science and academic discipline. Concepts, strategies, and methodologies are widely elaborated and discussed. The chemist faces challenges that belong to the domains of *science ethics* and *research ethics*, *engineering ethics* and *technology ethics*, and *profession ethics*. In some cases of applied chemical research it might touch the areas of *bioethics*, *medical ethics*, and *environmental ethics*.

According to the experience of the authors, many chemists don't want to spend any of their valuable working time reflecting on ethical issues. This is understandable since it is clearly beyond their professional competence, because this wasn't part of their education. Here, we talk about (singular) ethics as the professional discipline that requires certain competences and expertise. However, a lack of experience and expertise in ethics doesn't exonerate one from complying with moral values and ethical (as in plural *ethics*) guidelines. Morality and ethical commitment is possible without a degree in philosophy. The list of *ethically relevant topics* compiled in section 2 can help to clarify the roles that chemists may be expected to play in *Ethics in Chemistry*.

There are ethical aspects that are, actually, ethically clear. Most of these are found in the *internal domain*: Scientific misconduct, violation of safety regulations, or unfairness in education in most cases don't require *ethical competence*, but rather a higher degree of *moral integrity*. No normative assessment is necessary (anymore) to define and uncover *unethical* (or better: *immoral*) behavior in the professional role as chemist, supervisor, product developer, or chemical dealer. Here, the objective of *Ethics in Chemistry* is to increase the awareness for the moral pitfalls of chemical activity, to promote the compliance to ethical standards, to support whistle-blowing, and to help establishing an environment that gives incentives for morally acceptable conduct of a chemical profession. This last point is probably the most important one since a call for ethical integrity can only fall on nourishing grounds when there are clear and expectable advantages in the compliance to ethical standards. In cases beyond legal regulations—those with supererogatory character—an environment should be created that motivates and supports chemists to prioritise ethical conduct over fraud, compliance to standards over disregarding them, reflection of sustainability aspects over mere opportunistic considerations. Examples range from a reformation of the publication system, and its often criticised impact factors, to business models for sustainable distribution of chemicals (e.g. *chemical leasing*).

Then, there are those cases that need ethical analysis on the basis of normative premises (*values*) that—especially in dilemma cases—need to be reasoned by established ethical principles. Ethics as the *science of a good life* shall provide the person performing ethical reflection with an idea of what he or she *ought* to do. A variety of principles and methods have been elaborated in the past 2600 years (since the ancient Greek philosophers came up with this idea in the European cultural realm and Confucius did in East Asia) that—with different focus though—all have the same purpose: make the reflection reasonable and less arbitrary. The most basic concept (according to Aristotle) that every ethical argument must ground upon is logic. Such an argument that follows logic laws must contain three parts: a *descriptive* premise that tells *what is*, one or more *normative* (or *prescriptive*) premises that introduce the value that serves as the orientation for the decision-making, and a conclusion that due to the normative character of the prescriptive premises is also normative (telling what *ought to be* or what one *ought to do*). A normative conclusion from a descriptive premise without any prescriptive premise is called *naturalistic fallacy*. The distinct experts on normative reasoning are philosophers (more precisely: ethicists). However, in the field of *applied ethics* the findings depend strongly on the input of the experts of the scientific or societal entity that is observed. In the case of *chemical ethics*, chemists are the ones who know *what is*, the ones who bring in the descriptive premise as an ethical *hot spot* in the environment of their daily practice. By the nature of their job, they can't be expected to be experts on virtue ethics, categorical imperative or utilitarianism, but it may be expected that they know where their profession reveals ethical dimensions and where solutions of moral questions must be discussed. The interdisciplinary cooperation of chemists, ethicists, sociologists, and other participants of the debate can lead to productive and useful insights on the ethical and social dimensions of chemistry. In this interplay of various expertise the chemists deliver the foundation, the *what-is* premise without which the discourse would be speculative and meaningless.[41]

The way science is done today, highly embedded into a network of stakeholders and interests (like *technology assessment*, for example), enforces scientists to communicate their work to non-scientists and even the public to a much larger extent than before. In the recent decades, especially with the rise of biotechnology and genetic engineering, leading nations (particularly in the EU) responded to this problem by establishing the debate on ELSI as a part of science and technology development and governance—mostly visible in the field of nanosciences and nanotechnologies that is accompanied by an enormous effort to clarify and manage its social and ethical implications.[42] Chemists are and will be more and more confronted with situations in which they have to face an audience (research councils, media, public, etc.) that has science- and technology-related questions and concerns that actually belong to the field ofworldviews and values.[43] Chemistry and its enactors depend on public trust and support in its institutional and societal justification and performance. Therefore, it is also (but not only) the chemists' responsibility to create trust through a high degree of credibility and reliability as *experts* when it comes to (public) discourses on risks and benefits of science and technology or the ethical and social implications of scientific and technological progress.[44] Chemists as participants in this discourse who are aware of the social interrelations and ethical implications of their work, and who show that in their arguments and viewpoints, will earn more credibility and attention—and, ultimately, more influence—than scientists whose focus is too narrowly confined to their core expertise. Therefore, a necessity for chemists to look beyond the borders of their professional expertise and to sharpen their awareness and understanding of ethical and social dimensions of their work, can be identified.[45]

## 4. Conclusion: Towards Ethically Sound Science

Two domains of ethical issues have been identified. First, those related to profession and research ethics that are relevant within the chemical community and mostly in the responsibility of individual people (the chemists themselves), the internal domain; and second, those affecting the world outside of the institution chemistry, for example society and the environment, the external domain, covered rather by science and technology ethics and environmental ethics. Moreover, it has been pointed out that there are two kinds of ethical problems that require different modes of action: Those problems that are ethically clear (but for which it is a problem that chemists still behave unethically or immorally), and those that require deeper insight (and debate) into the ethical assessment of it. The role of chemists is different for these two different kinds of problems: In the former case, chemists need to *know* and *follow ethics*. Here, reflections on *Education for Ethics in Chemistry* and sense and non-sense of an *Ethos for Chemists* come into play. In the latter case, what is needed is *engaged chemists* that participate in ethical debates on science and technology development, for example in the scope of *technology assessment* (TA) or *ethical, legal, and social implications* (ELSI) research. It has been explained *why* that is important (*understand the normative foundations of underlying values andworldviews for a fruitful stakeholder debate!*) and *how* they can contribute efficiently with their expertise and competence (*deliver the input for the is-premise in the ethical argument!*). The times—politicians asking scientists for input for their (science and technology) decision-making—have never been more favorable for this participation and chemists should rise to the challenge!

In all cases, it has become clear, hopefully, in which way the engagement with ethics in the chemical professions is not only a fashion or optional spare-time activity, but pays off positively for everyone: For the chemist through increased academic and scientific success, higher credibility, and better career prospects; for the chemical community in terms of public trust and sound translation from science to technology to economy and business; and for society manifested in a more sustainable management of risks as well as social and environmental impacts.

Steps have been taken by the EuCheMS working party "Ethics in Chemistry" to establish a platform for chemists to collect, analyze, and communicate ethically relevant cases, to provide support and advice in ethical dilemmas, to help find answers to questions chemists are struggling with, and to actively support and encourage whistle-blowing that can uncover many cases of fraud and misconduct. Furthermore, it intends to serve as a platform for the collaborative elaboration of educational material for *Ethics in Chemistry*.[46] The existing work in this field to date requires a stronger contribution from chemists and needs an internal motivator and facilitator to support this interdisciplinary task which is what the EuCheMS working party *Ethics in Chemistry* intends to offer. Last but not least, it is the working party's objective to convince chemists of their role in ELSI and sustainability research and motivate and support them to participate actively whenever they have a chance. This goes along with providing a communication and networking platform and a contact pool for interested chemists and those who need the input of chemists for their work, for example, legislators, policy-makers, TA/ELSI/risk researchers, ethicists, and media. Through this collective effort, the goal of *building bridges* for more sustainability can be reached.

## *Acknowledgement*

The authors would like to express their gratitude and appreciation for the tremendous efforts undertaken by the initiators and founders of the EuCheMS working party "Ethics in Chemistry", Prof. Hartmut Frank and Prof. Francesco Dondi. Without their work and passion, the collaborative synergies that resulted in this article would not have been possible. Prof. Dondi left this world on November 2nd 2015. May his legacy and his spirit live on in publications like this!

**Keywords:** ethics in chemistry · good scientific practice · science and technology discourse · sustainability · responsibility

[1] a) *Technology and Society, Building our Sociotechnical Future* (Eds.: D. G. Johnson, J. M. Wetmore), MIT Press, Cambridge, USA, **2009**; b) *Shaping Emerging Technologies: Governance, Innovation, Discourse*, (Eds.: K. Konrad, C. Coenen, A. Dijkstra, C. Milburn, H. van Lente), IOS Press, Netherlands, **2013**.
[2] *Interdisciplinarity–Reconfigurations of the Social and Natural Sciences* (Eds.: A. Barry, G. Born), Routledge, Abingdon, UK, **2013**.
[3] U. Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch (Humboldt's Prussia: Emergence of Science and Technology)*, WBG, Darmstadt, Germany, **2015** (in German).
[4] *Science Worldviews and Education*, (Ed.: M. R. Matthews), Springer, Heidelberg, **2009**.
[5] For an overview: S. Matlin, G. Mehta, H. Hopf, *Science* **2015**, *347*, 1179.
[6] http://www.euchems.eu/divisions/ethics-in-chemistry/.
[7] T. Nieland, *Brauchen Ingenieure und Naturwissenschaftler Ethik oder reicht es aus, wenn sie moralisch sind? (Do engineers and natural scientists need Ethics, or is it sufficient when they comply to morals?), in Prolegomena–Philosophie, Natur und Technik"* (Eds.: K. Berr, J. H. Franz), Frank&Timme Verlag, Berlin, Germany, **2015**, pp. 49–62 (in German).
[8] For example: "*Encyclopedia of Applied Ethics*", (Ed.: R. Chadwick), 2nd edition, Elsevier, London, **2012**.
[9] As, for example, in: a) *Philosophy of Chemistry*, (Eds.: A. I. Woody, R. F. Hendry, P. Needham), Elsevier, Oxford, **2012**; b) D. Baird, E. Scerri, L. McIntyre, *Philosophy of Chemistry–Synthesis of a New Discipline*, Springer, Dordrecht, **2006**.
[10] For an overview: a) *Committee on Assessing Integrity in Research Environments (CAIRE), Integrity in Scientific Research*, The National Academies

 

Press, Washington, **2002**; b) J. Kovac, *The Ethical Chemist: Professionalism and Ethics in Science*, Prentice Hall, Upper Saddle River, **2003**; c) S. Loue, *Textbook of Research Ethics–Theory and Practice*, Kluwer, New York, **2002**; d) F. L. Macrina, *Scientific Integrity: An Introductory Text with Cases*", 3rd edition, American Society for Microbiology Press, Washington, **2005**; e) *On Being a Scientist: Responsible Conduct in Research*, 3rd edition, National Academy of Sciences, National Academy Press, Washington DC, **2009**; f) D. B. Resnik, *The Ethics of Science–An Introduction*, Routledge, London, **1998**; g) *Ethics for Graduate Researchers–A cross-disciplinary approach*, (Eds.: C. Russell, L. Hogan, M. Junker-Kenny), Elsevier, London, **2013**; h) K. S. Shrader-Frechette, *Ethics of Scientific Research*, Rowman&Littlefield, London, **1994**; i) *Research Ethics*, (Ed.: A. Smith Iltis), Routledge, New York, **2006**; j) C. N. Stewart, Jr., *Research Ethics for Scientists–A Companion for Students*, Wiley-Blackwell, Oxford, **2011**; k) *Science and Technology Ethics*, (Ed.: R. E. Spier), Routledge, London, UK, **2001**.

[11] D. Fenner, *Introduction to Applied Ethics (Einführung in die Angewandte Ethik)*, Narr Francke Attempto Verlag, Tübingen, Germany, **2010** (in German).

[12] B. C. Martinson, M. S. Anderson, R. de Vries, *Nature* **2005**, *435*, 737–738.

[13] D. Cyranoski, *Nature* **2014**, *505*, 468–471.

[14] More cases in: A. Briggle, *Scientific responsibility and misconduct, in Encyclopedia of Applied Ethics*, (Ed.: R. Chadwick), 2nd edition, Elsevier, London, **2012**.

[15] J. Pitt, *When is an Image not an Image?, in Nanotechnology Challenges. Implications for Philosophy, Ethics and Society* (Eds.: J. Schummer, D. Baird), World Scientific, Singapore, **2006**, pp. 131–141.

[16] K. S. Shrader-Frechette, *Tainted–How Philosophy of Science Can Expose Bad Science*, Oxford University Press, Oxford, **2014**.

[17] Overview: R. E. Spier, *Science and Engineering Ethics, Overview, in Encyclopedia of Applied Ethics*, (Ed.: R. Chadwick), 2nd edition, Elsevier, London, **2012**.

[18] R. Hoffmann, A. A. Kabanov, A. A. Golov, D. M. Proserpio, *Angew. Chem. Int. Ed.* **2016**, *55*, 10962–10976; *Angew. Chem.* **2016**, *128*, 11122–11139.

[19] Academia-related cases reported in: *Sexual Harassment at the Workplace*, (Ed.: M. Stockdale), Sage, London, UK, **1996**.

[20] *Chemistry as a Second Language: Chemical Education in a Globalized Society*, (Eds.: C. F. Lovitt, P. Kelter), ACS symposium series No.1049, Washington, USA, **2010**.

[21] G. Mohamedbhai, *The scourge of fraud and corruption in Higher Education*, International Higher Education, **2016**, *84*, pp. 12–14.

[22] C. H. Middlecamp, S. W. Keller, K. L. Anderson, A. K. Bentley, M. C. Cann, J. P. Ellis, *Chemistry in Context. Applying Chemistry to Society*, 7th ed., American Chemical Society, McGraw Hill, New York, USA, **2012**.

[23] P. L. Lallas, *Am. J. Int. Law* **2001**, *95*, 692–708.

[24] *Innovation, Dual Use, and Security–Managing the risks of emerging biological and chemical technologies*, (Ed.: J. B. Tucker), MIT Press, Cambridge, **2012**.

[25] S. O. Funtowicz, J. R. Ravetz, *Three types of risk assessment: Methodological analysis, in Risk analysis in the private sector*, (Eds.: C. Whipple, V. T. Covello), Plenum, New York, **1985**.

[26] a) A. E. Shamoo, D. B. Resnik, *Responsible Conduct of Research*, 3rd edition, Oxford University Press, Oxford, **2015**; b) M. J. Selgelid, *NanoEthics* **2009**, *3*, 175–183.

[27] S. Holm, E. Stokes, *Precautionary Principle, in Encyclopedia of Applied Ethics*, (Ed.: R. Chadwick), 2nd edition, Elsevier, London, **2012**.

[28] C. Blackmore, *Sustainability, in Encyclopedia of Applied Ethics*, (Ed.: R. Chadwick), 2nd edition, Elsevier, London, **2012**.

[29] Principle 7 of the Rio Declaration on Environment and Development.

[30] Principle 16 of the Rio Declaration on Environment and Development.

[31] *White Paper: Strategy for a Future Chemicals Policy*. Commission of the European Communities, Brussels, **2001**. http://eur-lex.europa.eu/LexUriServ/site/en/com/2001/com2001 0088en01.pdf.

[32] a) H. Jonas, *The Imperative of Responsibility: In Search of an Ethics for the Technological Age*, University of Chicago Press, Chicago, USA **1984**; b) U. Beck, *Risk Society: Towards a New Modernity*, Sage, London, UK **1992**.

[33] a) A. Chapman, *Democratizing Technology. Risk, Responsibility & the Regulation of Chemicals*, Earthscan, London, UK, **2007**; b) J. Martinez-Alier, *The Environmentalism of the poor. A Study of Ecological Conflicts and Valuation*, Edward Elgar, Cheltenham, UK, **2002**.

[34] A. Hullmann, *European Activities in the Field of Ethical, Legal and Social Aspects (ELSA) and Governance of Nanotechnology*, European Commission, DG Research, **2008**.

[35] a) S. A. Matlin, G. Mehta, H. Hopf, A. Krief, *Nat. Chem.* **2016**, *8*, 393–398; b) S. A. Matlin, G. Mehta, H. Hopf, A. Krief, *Nat. Chem.* **2015**, *7*, 941–943.

[36] https://www.opcw.org/special-sections/science-technology/the-hague-ethical-guidelines/.

[37] F. Moser, F. Dondi, "On the road to Rio + 20: The role of international environmental governance and of the evolution of environmental ethics for a safer world", *Toxicol. Environ. Chem.* **2012**, *94*, 807–813.

[38] a) T. Kerns, *Environmentally Induced Illnesses: Ethics, Risk Assessment and Human Rights*, McFarland & Co., Jefferson, USA, **2001**; b) K. S. Shrader-Frechette, *Environmental Justice*, Oxford University Press, New York, USA, **2002**.

[39] H. Frank, L. Campanella, F. Dondi, J. Mehlich, E. Leitner, G. Rossi, K. Ndjoko Ioset, G. Bringmann, *Angew. Chem. Int. Ed.* **2011**, *50*, 8482–8490; *Angew. Chem.* **2011**, *123*, 8632–8641.

[40] U. N. General Assembly, 66th Session, *The future we want: resolution 66/228 adopted by the General Assembly* (A/RES/66/288), **2012**.

[41] M. Cotton, *Ethics and Technology Assessment: A participatory approach*, Springer, Berlin, Germany, **2014**.

[42] One example for countless publications: *In Pursuit of Nanoethics*, (Eds.: B. Gordijn, A. M. Cutter), Springer, Dordrecht, Netherlands, **2014**.

[43] O. Renn, *Risk Governance–Coping with Uncertainty in a Complex World*, Earthscan, London, UK, **2008**.

[44] *Experts in Science and Society*, (Eds.: E. Kurz-Milcke, G. Gigerenzer), Kluwer, New York, USA, **2004**.

[45] See also: B. Bensaude-Vincent, J. Simon, *Chemistry, the Impure Science*, 2nd edition, Imperial College Press, London, UK, **2012**.

[46] Special issue: a) Ethics and Responsible Conduct of Research within the Chemical Community. Ideas and Experiences Worth Sharing, (Ed.: J. I. Seeman), *Account. Res.*, **2015**, volume *22*, issue 6; b) J. Kovac, "Ethics in Science: The Unique Consequences of Chemistry", *Account. Res.*, **2015**, *22*, 312–329.

Manuscript received: November 11, 2016
Final Article published: January 20, 2017

 