Education for Ethics in Chemistry Based on Case Studies

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This monograph examines the evolving landscape of education for ethics in the chemical sciences, with particular emphasis on case-based pedagogical approaches. Drawing on the foundational work of ACS Committee on Ethics members and global frameworks, the monograph advocates for the longitudinal integration of ethical awareness into the professional education and career development of chemists. Through the use of relevant case studies, the chemistry community can cultivate a culture of integrity that sustains public trust in science.

Basic Frameworks

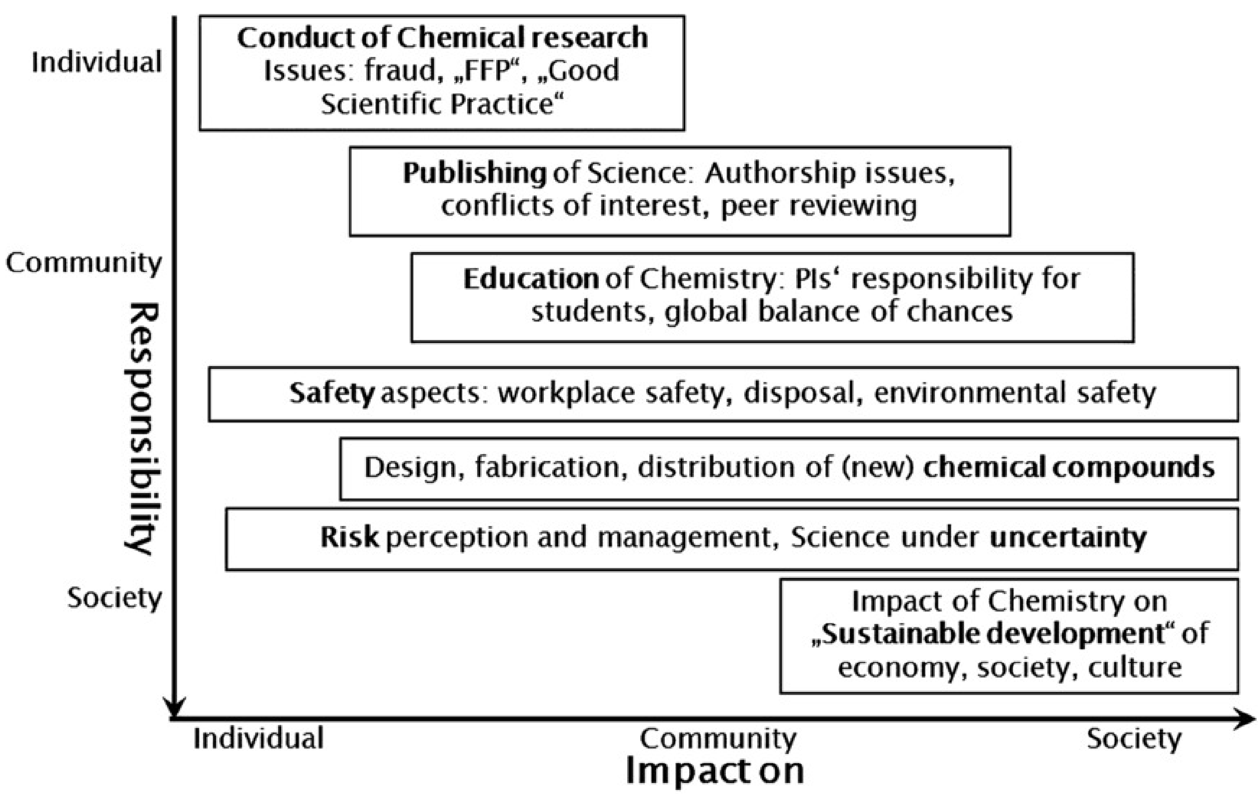
In the first few years following its establishment in 2006, the ACS Committee on Ethics members wrote or collected case studies about ambiguous situations.[1] These case studies provided the basis for the six workshops at various regional meetings that have engaged members, particularly students, in discussions to guide their future actions.[2] The committee's collection included thirteen case studies relating to chemical health and safety, interpersonal dynamics, collecting and managing data, cheating, dishonesty, and plagiarism. It was published on the ACS website.[3] Concurrently, in 2008, Ellen Fisher and Nancy Levinger published a direct framework for integrating ethics into chemistry curricula using real and fictional case studies.[4] The authors classified a range of scenarios matching the complexity of cases for the appropriate experiences of students. They reviewed literature, described various case studies for discussions (complemented by data tables and supplementary materials), and concluded that "discussions of case studies are an effective and enjoyable way to teach scientists with different levels of preparation."[4]

Ethical Dimensions

Another classification of ethical issues in chemistry was described in the 2017 editorial by the members of the Ethics in Chemistry working party of the European Chemical Society (EuCheMS).[5]

The authors categorized the ethical cases into two domains, internal and external, and then into three areas related to 1) the work of an individual chemist, 2) the performance of the chemical community, and 3) the impact that chemistry has on societal, economic, and environmental spheres. The internal domain encompasses good research practices outlined in professional guidelines for scientific integrity including scholarly publications, safety aspects, and mentor-student relationships. The external domain is concerned with the invention of new chemical substances, their potential to be used in a variety of applied fields, and continuous considerations of dual use dilemmas. The authors emphasized the ethical tension involved in determining "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."[5]

The ethical and social dimensions of chemistry described by the authors are summarized in the following chart:



FFP: fabrication, falsification, plagiarism

Figure 1: Overview of internal and external ethical and social dimensions of chemistry (reprinted with permission from the publisher Wiley-VCH GmbH).[5]

Narrative Pedagogy

Ethical dilemmas associated with the publication of chemical research are explored in the ACS symposium book *Credit Where Credit Is Due: Respecting Authorship and Intellectual Property,* edited by two former members of the ACS Committee on Ethics, Judith Currano and Patricia Mabrouk.[6] In this volume, the scenarios for discussions were written by two renowned educators, Jeffrey Kovac and John D'Angelo. They described situations for advanced students and early career researchers that might arise among multiple authors of a manuscript, hierarchy for credit by authors and contributors, relationship between student authors and their advisors, issues with self-plagiarism, quantity versus quality of research, and the role of the journal impact factor in evaluating publications.

A cornerstone of modern chemistry ethics is the recognition that misconduct is often a pedagogical failure rather than a purely individual one. Former ACS Committee on Ethics member John D'Angelo, in his work *Ethics in Science: Ethical Misconduct in Scientific Research*, framed education as the primary mechanism for preventing misconduct.[7] He advocated for a culture where ethical standards are reinforced through repeated exposure, potentially becoming a module applied in settings from high school through professional training. D'Angelo classified misconduct into three areas: 1) *crimes against science:* violations that harm the integrity of scientific knowledge, such as the falsification and fabrication of data or the deliberate omission of data that contradicts a hypothesis; 2) c*rimes against researchers:* violations involving ownership and authorship, such as passing off another's data as one's own, publishing results without consent, or failing to acknowledge contributors, and 3) *other violations*: broad ethical breaches including conflict of interest, misconduct involving human or animal subjects, and violations during the peer review process. Looking into the future, in 2018, D'Angelo raised questions about artificial intelligence (AI) by providing brief explanations of the Asilomar AI Principles.[8] Modern curricula must focus on "Human Control" and "Value Alignment" to ensure that AI performs only designated objectives and avoids lethal autonomous applications. In addition to scenarios presented throughout the text, the book provided descriptions of equivocal real-world scenarios with a summary of the disputes, resolutions, and questions for the readers to engage them in lively conversations. For example, in this part one can find a case study on: Autism and the Measles, Mumps and Rubella Vaccine.

Next, in 2020, the ACS Committee on Ethics member Kelly Elkins (in collaboration with a student Fambegbe Ibiwunmi) discussed approaches to teaching ethics with an emphasis on the case study method in forensic science.[9] They presented real scenarios of ethical issues mapping them to the topics identified by ACS members in the 2019 survey. The discussion addressed topics that dealt with accountability, assignment of credit, conflict of interest, data integrity, data ownership, environmental stewardship, peer review, regulation, research funding, respect, safety, and theft.

The authors suggested ways for incorporating the case studies into presentations, discussions, and critiques for active participation by students.

Global Perspectives

Both D'Angelo and Elkins emphasize case-based learning as an effective pedagogical method for ethics education. This approach is uniquely suited to chemistry, where ethical decision-making can be embedded in experimental design, data interpretation, and collaboration. During that time, the consideration of "Ethical Case Studies of Chemistry" was the theme for the four special issues of *HYLE - International Journal for Philosophy of Chemistry* from 2016 to 2020.[10] Four years later, Liliana Mammino reflected on the HYLE's special issues with an eye toward the important role of ethics in sustainability objectives and environmental issues.[11] For that perspective, the author suggested the incorporation of ethics into chemistry education within its typical contexts with discussions of the nature and behaviors of substances, the benefits and adverse effects of their usage, and the strategies how to maximize the former and minimize the latter. Mammino concurred that active engagement and reflection on ethical dilemmas by students are the most impactful on their development as scientists and citizens. Pedagogy is increasingly linked to environmental stewardship, such as the 12 Principles of Green Chemistry, which move away from a "take-make-dispose" model.[12]

Emerging Dilemmas

Emerging ethical dilemmas in chemistry increasingly arise from global scientific collaboration, technological advances, and societal expectations regarding responsible innovation. International organizations such as the International Union of Pure and Applied Chemistry (IUPAC) have therefore developed frameworks to guide ethical conduct across national and disciplinary boundaries. These initiatives emphasize that while ethical standards are shared across the profession, their application is influenced by local contexts and international collaboration. The *IUPAC Guiding Principles for Responsible Chemistry* (2025) encourage chemists to take individual responsibility for their professional behavior while promoting collective responsibility within organizations.[13] Mark Cesa was the 2024-2025 chair of the IUPAC Standing Committee on Ethics, Diversity, Equity and Inclusion, and a member of the ACS Committee on Ethics. The IUPAC Guiding Principles include eight modules on responsible innovation; ethical behavior; communication and collaboration; integrity and accuracy; safety, security and sustainability; inclusivity, equity and belonging; equitable access; and convergence across disciplines. Each module consists of the topic overview, examples, guidelines for future actions, questions to guide discussion, and references. They may be used as case studies in academia and in industrial settings.

Longitudinal Integration

A consistent theme across ACS and IUPAC efforts is the necessity of weaving ethics into the fabric of chemistry instruction rather than treating it as an isolated subject.

Table 1. Examples of integrating ethics across chemistry instruction

Instructional Area	**Ethical Focus**
Analytical Chemistry	Data integrity, reproducibility, and transparent reporting
Research Projects	Authorship norms, collaboration, and mentorship responsibilities
Laboratory Instruction	Safety protocols (RAMP), chemical security, and risk assessment
Professional Skills	Conflict of interest, peer review process, and public outreach

Through this repeated exposure, students internalize ethical standards as a core component of their professional identity. This process is vital for maintaining public trust that is critical to the survival of the scientific community.

Collections of viewpoints by committee members, such as the recent compilation the *Memorable Moments and Reflections on Ethics* serve as narrative records of encounters with ethical dilemmas.[14] These reflections humanize ethical decision-making, demonstrating that it is a learned practice shaped by community standards and professional norms.

Concluding Reflections

As John D'Angelo noted, the loss of public trust in science is a critical threat that we must not let happen. Teaching ethics in chemistry is an act of professional stewardship. By documenting and reflecting on these educational practices, the ACS Committee on Ethics affirms that ethical reasoning is inseparable from technical competence, ensuring that chemistry remains a transparent and beneficial force for society.

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We also want to highlight the forthcoming 2026 ACS Symposium Series book "Ethics for Transformation: Ethics and Standards in the Global Chemical Enterprise" edited by Susan Schelble and Kelly Elkins.