

The Importance of Ethical Conduct in Scientific Research

Dr. Laurence Doemeny, Ph.D. and Dr. Patrick Knerr, Ph.D.
Committee on Ethics, American Chemical Society
November 2017

“The ultimate purpose in studying ethics is not as it is in other inquiries, the attainment of theoretical knowledge; we are not conducting this inquiry in order to know what virtue is, but in order to become good...” ~ Nicomachean Ethics, Book 2, Chapter 2 (1)

To become good throughout one’s career, and indeed throughout one’s life, is not a journey with a defined end point, but a continuous process that requires integrity, honesty, and frequent self-reflection. In the field of scientific research, both innovation and accurate reporting of information are critical to society, and society implicitly trusts scientists and researchers to be ethical and honest in their work. The need for data reliability has become even more profound as technology advances at an ever increasing rate. Indeed, the tools of “big data,” with its advances in statistical applications, have made it easier than ever to detect unethical behavior. Once an individual is associated with such behavior - once the implicit trust in their scientific integrity is broken - it becomes almost impossible to recover that reputation. When beginning the educational process, one's reputation is unvarnished, and during advancement into and through the workplace, this reputation for honesty and integrity should likewise progress. Without a doubt, this integrity is critical to find employment, to obtain research grants, to disseminate important findings, and generally to be a successful and respected scientific professional.

Unethical behavior has occurred for centuries and has been perpetrated by famous scientists, including Isaac Newton, John Dalton, and Robert Millikan (2; 3). The offenses are often revealed in data that were “too good,” lacking even a hint of random - and perfectly acceptable - error or variation. Even today, statistical rigor and proper experimental design are lacking in many studies. Yet not all misconduct involves data falsification (“cleaning of the data”) or data fabrication (“making up the data”). Plagiarism and misappropriation of contribution are forms of theft that intrude on proper acknowledgment of the original work, which cost the true owner time, effort, and, in many cases, money. For the individual committing such a theft, there could be gratification and recognition in the short term... until the offense is discovered. Despite the risks and unethical nature of such behavior, studies have shown that plagiarism occurs more often than commonly appreciated (4).

This document serves as an introduction to the importance of ethical behavior in scientific research, beginning with some well-known examples of unethical conduct and their severe consequences. For additional examples, the Department of Health and Human Services (DHHS) Office of Research Integrity lists case studies of misconduct dating back to 2008 (5). Many of these cases involve data fabrication or falsification in scientific publications, poster sessions, and grant applications. Like DHHS, the National Science Foundation maintains a compendium of misconduct investigations available to the public (6). Cases can be searched by the type of misconduct in 32 categories, such as plagiarism, data tampering, data falsification, sabotage, and intellectual theft. This database also identifies the repercussions in these cases; a brief scan reveals that punishments can be severe, possibly involving job loss, revoked academic degrees, and even criminal charges.

Examples of Unethical Behavior and Long-Term Effects

Scientific progress necessitates the ability of independent researchers to reproduce experimental observations. Oftentimes, fraudulent research is eventually uncovered when it cannot be reproduced, though it may take years to unravel fully. Take the example of Jan Hendrik Schön, a German physicist studying organic semiconductors at Bell Laboratories in the 1990s. Schön used fabricated data to support claims of making organic transistors, a long-desired breakthrough in the development of advanced electronics (7). The published data were found to be fabricated following reports of irreproducible results from other researchers over several years, and from 2002 to 2003 over 25 of his papers were retracted. Subsequently, Schön saw his doctoral degree revoked from the University of Konstanz for dishonorable conduct, as well as a host of international research awards.

A similar case involves former Columbia University graduate student Bengü Sezen (8). During her graduate work involving the development of C-H bond functionalization reactions, fellow lab members had raised concerns about the reproducibility of her findings, which led to three of them being dismissed from the university. Despite the growing evidence of possible misconduct, the university elected to award Sezen a Ph.D. degree with distinction in 2005. Just weeks after receiving her degree, Sezen was accused of fabricating data in an ACS publication by a Columbia University report, and the university formed an inquiry committee. Over the course of the following five years, six papers were retracted and her Ph.D. degree revoked. Perplexingly, Columbia administrators have remained largely silent about this case beyond the formal report, and the university has further forbidden Sezen's research advisor and other employees from speaking publicly. However, it has been speculated that the impending tenure decision of Sezen's advisor during her time at the university may have played a role in motivating the deceit.

Scientific misconduct can also have profound effects on the criminal justice system. The investigation of a state crime laboratory in Jamaica Plain, Massachusetts, from 2012-2014 uncovered not only flagrant misconduct by an individual chemist, but also failures at the management level to act promptly on the discovery of such misconduct. The detailed police report revealed that management was not properly responding to allegations of falsified data, forged signatures, and perjury. The investigation included a review of all laboratory employees, protocols, chain-of-custody procedures, and sample analyses, covering some 34,000 cases (9). In 2013, chemist Annie Dookhan was sentenced to a three-to-five year term of imprisonment after pleading guilty to falsification of thousands of drug tests over several years. It has been estimated that up to 40,000 people may have been falsely convicted of drug-related offenses due to her misconduct (10).

Among the most critical applications of scientific research is the advancement of public health and quality of life. Scientific misconduct not only impacts the perpetrator's career and wastes already finite resources, but may even put lives at risk. In this regard, several cases stand out as tragic examples of the grave impact that scientific misconduct can have in the medical field. In the infamous *Tuskegee Syphilis Study* (11), participants were not informed of the nature of the study, which sought to examine the progression of untreated syphilis in African-American men. The study subjects were left untreated for up to 25 years, despite the availability of an effective treatment. By the time the study was forced to end and the subjects finally treated, 100 participants had died, and 40 wives and 19 children had also contracted the disease. However, discovery of this study also catalyzed the development of modern bioethical review procedures for the use of human subjects in the U.S., in order to prevent a similar tragedy from happening in the future.

The damaging effects of unethical conduct can go far beyond the individuals directly associated with the case, having far-reaching implications for public health. Such is the case of former British surgeon and researcher Andrew Wakefield, whose fraudulent 1998 paper claimed an association

between the measles, mumps, and rubella (MMR) vaccine and autism (12). Despite the fact that the results - and Wakefield himself - were widely discredited by a multitude of other scientific and medical professionals, and that repeated independent investigations over a 20 year period have revealed no association, Wakefield has catalyzed a vocal anti-vaccine advocacy that continues to propagate this belief and influence parents to decline vaccinations for their children. Accordingly, an increase in the occurrence of measles in the U.S. has been attributed to decreasing rates of MMR vaccination (13) (14).

Perhaps an even further-reaching example is leaded gasoline. The long and deleterious history of lead poisoning on public health in the modern world is well studied, and some scholars even attribute lead poisoning as a contributing factor to the fall of the Roman Empire (15). In the early 20th century, automobile internal combustion engines often experienced knocking due to abnormal combustion, which affected performance and could even destroy the engine (16). The competitive search for an antiknock compound to improve engine performance resulted in the addition of tetraethyl lead - a neurotoxin that accumulates in humans over time - to gasoline. Less hazardous alternatives with comparable performance, including several alcohols, were known at the time of tetraethyl lead's introduction in the 1920s. In fact, Neal deGrasse Tyson devotes Episode 7 of his *Cosmos: A Spacetime Odyssey* to the debate that raged into the 1960s over this environmental and public health threat (17). It was during this time that Robert Kehoe, M.D., of the University of Cincinnati and Alice Hamilton, M.D., of Harvard Medical School tussled over the risk and impact of tetraethyl lead toxicity. As a paid representative of the auto fuels industry, Kehoe demanded definitive proof that the additive was injuring people before any agreement to remove the compound would be considered (18). Ultimately, geochemist Clair Patterson of the California Institute of Technology presented such evidence in 1965, which eventually prompted the fuel industry to phase out tetraethyl lead in favor of many of the less-toxic alternatives known over forty years earlier. We may never know the full impact of the decades-long use of tetraethyl lead in auto fuels, but sub-toxic exposure to lead is now well established to affect the intellectual development of children (19) (20).

Even in the 21st century, another ethical breach is playing out relating to vehicle emissions involving over 11 million "low emission" diesel automobiles manufactured by Volkswagen and sold around the world between 2009 and 2015. Allegations emerged in 2015 that the engine software operates the car in a "low emission" mode only when the vehicle is being tested to meet emission requirements; yet when operated under normal driving conditions, this software goes offline, and the vehicle emits NO_x pollutants up to 40 times above the legal limit. This case is both interesting and tragic to follow, since it involves deliberate and creative engineering to circumvent testing and regulatory requirements, as well as substantial public health consequences due to the extensive release of hazardous air pollutants. Also intriguing are the explanations of how such an expansive fraud was allowed to happen, whether to accelerate product development, reduce of the cost of manufacturing, or increase sales through deceptive advertising. Volkswagen's stock price fell nearly 30% in the days following the initial allegations, and billions of dollars have been spent by the company in criminal fines and vehicle recall campaigns (21).

Ethical Behavior of Scientific Professionals

The above cases unfortunately represent just a handful of the many examples of scientific misconduct too numerous to list. This is not meant to dishearten the scientific community, but on the contrary, to empower it to learn from past mistakes and to continue advocating for the integrity on which scientific progress is built. As a rebuttal to such unethical behaviors, the American Chemical Society (ACS) and the National Institutes of Health (NIH) Office of Research Integrity, among others, offer guidelines for scientific professionals on how to act responsibly and avoid unethical conduct. All of the above tragedies could have been prevented had the ACS Code of Professional Conduct, below, been followed.

ACS Code of Professional Conduct: Chemical Professionals Acknowledge Their Responsibilities

To the Public

Chemical professionals have a responsibility to serve the public interest and safety and to further advance the knowledge of science. They should actively be concerned with the health and safety of co-workers, consumers and the community. Public comments on scientific matters should be made with care and accuracy, without unsubstantiated, exaggerated, or premature statements.

To the Science of Chemistry

Chemical professionals should seek to advance chemical science, understand the limitations of their knowledge, and respect the truth. They should ensure that their scientific contributions, and those of their collaborators, are thorough, accurate, and unbiased in design, implementation, and presentation.

To the Profession

Chemical professionals should strive to remain current with developments in their field, share ideas and information, keep accurate and complete laboratory records, maintain integrity in all conduct and publications, and give due credit to the contributions of others. Conflicts of interest and scientific misconduct, such as fabrication, falsification, and plagiarism, are incompatible with this Code.

To Their Employer

Chemical professionals should promote and protect the legitimate interests of their employers, perform work honestly, competently, comply with safety policies and procedures, fulfill obligations, and safeguard proprietary and confidential business information.

To Their Employees

Chemical professionals, as employers, should respect the professionalism of their subordinates and have concern for their well-being, without bias. Employers should provide them with a safe, congenial working environment, fair compensation, opportunities for advancement, and properly acknowledge their scientific contributions.

To Students

Chemical professionals should regard the tutelage of students as a trust conferred by society for the promotion of the students' learning, professional development, and safety. Each student should be treated fairly, respectfully, and without exploitation.

To Colleagues

Chemical professionals should treat colleagues with respect, encourage them, learn with them, share ideas honestly, and give credit for their contributions. Chemical professionals should carefully avoid any bias based on race, gender, age, religion, ethnicity, nationality, sexual orientation, gender expression, gender identity, presence of disabilities, educational background, or other personal attributes. They should show consistent respect to colleagues, regardless of the level of their formal education and whether they are from industry, government or academia, or other scientific and engineering disciplines.

To Their Clients

Chemical professionals should serve clients faithfully and incorruptibly, respect confidentiality, advise honestly, and charge fairly.

To the Environment

Chemical professionals should strive to do their work in ways that are safe for both the environment and for the health of all who may be affected. They have a responsibility to understand the health, safety and environmental impacts of their work, to recognize the constraints of limited resources, and to develop sustainable products and processes that protect the health, safety, and prosperity of future generations.

Many scientific organizations, including the ACS through its Committee on Ethics, Division of Professional Relations, and Committee on Economic and Professional Affairs, have active programs and resources for raising awareness of principles and issues related to scientific ethics. Many institutions have definitions and categories of scientific misconduct, such as the NIH Office of Research Integrity in its extensive 2007 publication *Introduction to the Responsible Conduct of Research*, which covers authorship, institutional and human subject boards, data collection, analysis, and much more (22). This work can serve as a valuable reference for scientific ethics for researchers regardless of the setting or field.

Ethical conduct of research is critical not just for scientific professionals and the scientific enterprise. Society at large depends on innovation in many disciplines to address emerging health, environmental, and technological challenges, and therefore to improve quality of life. So, as a member of this profession, be original, be virtuous, and do good.

Acknowledgment

The authors thank 2016 and 2017 members of the ACS Committee on Ethics for suggestions and support in constructing this document.

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