

ETHICAL CONSIDERATIONS ON CHEMISTRY EDUCATION AND PRACTICE

Mary Nneora Muoneke
Integrated Science Department
School of Secondary Education Science Programme
Federal College of Education, Obudu
Cross River State

And

Vitus Chidozie Muoneke
Dulux Company Centre
115 Ikot Ekpene Road
Besides Keystones Bank
Uyo

Abstract

This paper explores the ethical considerations of chemistry education as well as practices of unethical behaviours by the chemists. First, the definition of terms and codes of ethics of conduct, as well as the significance of ethics in chemistry education, and ethics in the laboratory are discussed. Chemical weapons and other dangerous substances and environmental pollution and green chemistry make chemists (chemistry teachers inclusive) prone to other unethical behaviours that need more attention.

Keywords: Ethics, code of conduct, ethical considerations, chemistry education and practice.

Chemistry is the science that deals with the properties, composition, and structure of substances (defined as elements and compounds), the transformations they undergo, and the energy that is released or absorbed during these processes (Pakhshi & Rarh, 2012). Every substance, whether naturally occurring or artificially produced, consists of one or more of the hundred-odd species of atoms that have been identified as elements. Although these atoms, in turn are composed of more elementary particles, they are the basic building blocks of chemical substances; there is no quantity of oxygen, mercury, or gold, for example, smaller than an atom of the substance. Chemistry, therefore, is concerned not with the subatomic domain but with the properties of atoms and the laws governing their combinations and how the knowledge of these properties can be used to achieve specific purposes.

The significant role of chemistry education in the society cannot be overemphasized. According to Simon (2018), Chemistry education is the study of teaching and learning chemistry, it is a subset of STEM education or discipline based education research. It has a wide range of topics that include understanding how students learn chemistry and determining the most efficient method of teaching chemistry. Hence, there is a constant need to improve chemistry curriculum and learning outcomes based on chemistry education research. Chemistry Education is concerned with the impartment of knowledge on properties, components, transformations and interactions of matter (Ababio, 2013). Chemistry Education is therefore the systematic process of acquiring the fundamental knowledge about the universe. Chemistry Education, in its all-embracing and complex ramification can be seen as the acquisition of knowledge or ideals relevant to chemistry, (Muoneke, Asagha, & Muoneke, 2021).

Chemistry education can be improved by changing teaching methods and providing appropriate training to chemistry instructors, within many modes including classroom teaching, demonstrations, and laboratory activities. Moreover, O'Neill and Bourke (2010) assert that in the moral climate of public education, most people would agree that teachers have a personal and collective responsibility to be ethical in their work with students, families, colleagues and the wider education. The teacher, upon entering the teaching profession, assumes a number of obligations, one of which is to adhere to a set of principles which defines professional conduct. Chemistry education is important because the field of chemistry is fundamental to the world. The universe is subject to the laws of chemistry while human beings depend on the orderly progress of chemical reactions with their bodies. Described as the central science, chemistry connects physical sciences with the life sciences and applied sciences. Chemistry has application in food, medicine, industry, the environment and other areas. Learning chemistry allows students to learn about the scientific method and gain skills in critical thinking, deductive reasoning, problem solving, and communication. Teaching chemistry to students at a young age can increase student interest in STEM careers. Chemistry also provides students with man transferable skills that can be applied to any career.

With the above meaning and importance of not only chemistry but also chemistry Education, how do we preserve and improve the health and safety of the planet? What are the roles and consequences of the chemicals we produce, and how do we produce and manage them? What responsibilities do we have regarding the creation and manufacture of weapons—all of which are “chemical” in one way or another? What makes chemistry unique? And how does this uniqueness reflect on chemistry’s unique concerns with ethics? Hoffmann (2012) argues, it is because chemistry is in the “tense middle,” occupying a space between several pairs of extremes. Most importantly, chemistry has always inhabited a frontier between science and technology, the pure and the applied, the theoretical and the practical (Beauchamp & Childress, 2009). Unlike the other natural sciences, chemistry traces its origins to both philosophy and the craft tradition. Chemists are discoverers of knowledge and creators of new substances.

Ethical Considerations on Chemistry Education and Practice

The objects of study in chemistry, molecules and the macroscopic systems made up of molecules, are intermediate between the very small, the elementary particles, and the very large, the cosmos. Chemical systems are the right size to affect humans directly, for better or worse. They are the building blocks of biological organisms; they are the substances we eat and drink; they are the drugs that have dramatically improved human health over the past century; they comprise the materials that we use to construct the products that we use daily; but they are also the environmental pollutants that can plague our world. Chemicals can also be used as weapons (Rachels, 2012). Ethical considerations on chemistry education and practice may be considered as that accumulation of scientific and professional principles of human values or development that improves teachers and students in tertiary institutions. The purpose is also to facilitate the development of methods and application of these methods to improve the condition of teachers, families and communities for or across environmental integrity, economic viability, succession, safety of lives and properties, and a just and egalitarian society for both the good of the present and future generations, while respecting cultural diversity (Allison Academy, 2021).

Concepts of Ethical Considerations/Chemistry/Chemistry Education/Ethical Practices

The major concepts of this paper may be briefly explained as follows:

Chemistry Education

Chemistry Education is concerned with the impartment of knowledge on properties, components, transformations and interaction of matter (Ababio, 2013). Chemistry Education is therefore the systematic process of acquiring the fundamental knowledge about the universe. Chemistry education, in its all-embracing and complex ramification can be seen as the acquisition of knowledge or ideals relevant to chemistry (Muoneke, Asagha, & Muoneke, 2021).

Ethical considerations

Ethics and its consideration is explained differently by authors. According to Bhasin (2020), ethical consideration is a collection of principles and values that should be followed while doing human affairs. Ethics searches for reasons for acting or refraining from acting; for approving or not approving conduct; for believing or denying something about virtuous or vicious conduct or evil rules, (Australian Law Reform Commission, 2021). Moreso, ethical considerations make sure that no human rights are violated and research being conducted has no hidden agenda. On the other hand ethical practice involves a human subject's right to autonomy and the ability to make an independent decision, without coercion, involving informed consent and privacy,(Lawrie, Graulich, Kahveci & Lewis,2021). They also emphasized that participants in chemistry education research are typically either teachers or students.

Codes of Ethics

A lot of attempts have been made to integrate ethical considerations on chemistry and ethical practices, Jeffrey Kovac by comparing the American Chemical Society (ACS) codes with the followings: i) British and German chemical societies; ii) The more recent International codes, the Hague Ethical Guidelines; and , iii) The Global Chemists' Code of Ethics, (Schummer & Borsen, 2021). In support of the view of the paper, Kovac, (2018) argues that a future revision of the American Chemical Society (ACS) code of ethics should put more emphasis on research integrity and on societal and environmental issues.

The Chemist's Code of Conduct of the American Chemical Society presumably applies to all chemists (American Chemical Society, 2012). It lists the responsibilities of chemists to various groups beginning with the responsibilities of chemists to the public: Chemists have a professional responsibility to serve the public interest and welfare and to further knowledge of the science. Chemists should actively be concerned with the health and welfare of coworkers, consumers and the community. Public comments on scientific matters should be made with care and precision, without unsubstantiated, exaggerated, or premature statements. (American Chemical Society, 2012).

Significance of Ethics in Chemistry Education

If a scientist fabricates data, wrongly assumes authorship of something that some colleagues have achieved before, or if senior scientists put their name first (or last, depending on the customs of the discipline) on the publication of work mostly done by junior scientists, or if someone denigrates the public image of science, the scientific community is usually upset. There is no question that all that is bad behavior. However, does it really concern general ethics? While it is, in any regard, morally wrong to betray somebody else, like your colleagues and the general public with fabricated results, it is not so clear if the other issues scientists are usually concerned with are of ethical relevance (Avi & Eilks, 2015). These actions are unethical.

The practice of chemistry, and all other sciences, raises ethical questions on several levels. Many of these questions arise from the day-to-day work in the laboratory: the responsible conduct of research. Others are related to the relationships of chemists to their colleagues and to the relationship between science and society. To put these questions in context, we need to understand the nature of professional ethics and the moral ideals that underlie the profession of science. According to Kovac (2018) these issues derive, in part, from the nature of chemistry as a science, a science that does not fit the neat picture that is drawn in the first chapter of textbooks. They also derive from the fact that ethics is an inquiry into right human conduct: What is a good life? Chemistry has contributed more to the betterment of human life than any other science, but at the same time has also contributed significantly to the deterioration of the environment. To develop a more complete picture of the nature of chemistry, we need to examine the distinction between pure and applied research more carefully. The geographic center of

Ethical Considerations on Chemistry Education and Practice

chemistry is in the laboratory, a place where scientific knowledge and technique meet. Whatever the chemical experiment, synthesis, analysis, determination of physical, or chemical properties—technique is important. Early chemistry books were filled with recipes, ways to make or isolate substances. This is because there was no controlling body like a profession in other areas such as in medical practice.

A profession is a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a moral ideal in a morally-permissible way beyond what law, market and morality would otherwise require (Schummar, 2018). He goes on to say that a code of ethics is a central feature of a profession. Chemistry fits this definition and codes of ethics have been adopted by the American Chemical Society (American Chemical Society, 2012),

Furthermore, because science is a form of public knowledge, an ideal of open communication is needed, the ideal of the gift economy. The gifts of the scientist's research through open communication are what sustain the growth of knowledge. Secrecy is an anathema to the health and progress of science. The ideal of open communication based on the concept of the gift economy is more problematic, particularly when commercial interests are involved, so this will be the topic of some discussion below. Finally, because science has uses there must be an ideal that governs the choice of applications. Chemistry is a complex mixture of the fundamental and the applied and because the products of chemistry substantially affect our daily lives, ethical questions related to the uses of chemicals are a central concern. Certainly, other sciences have ethical concerns. Physicists, for example, are involved in the debates regarding the use of nuclear power. Biotechnology has raised questions related to the use of genetically-modified organisms and human cloning. All of these are important, but the products of chemistry, drugs, food additives, personal care products, detergents, as well as the effects of environmental pollution, permeate our lives.

Additionally, all chemists simultaneously belong to several communities and each has its own set of responsibilities. Each of Chemists is a citizen of a national society with a history, goals and ideals. With citizenship comes obligations; Secondly, the chemist is a member of a profession subject to the broad professional ethics of science and the more specific codes of ethics of chemistry. Thirdly, almost all chemists are employed by an institution, a college or university, a government or private research laboratory, a government agency, or a corporation. Each of these has its own culture and expectations. Simultaneous membership in these different communities can certainly give rise to moral dilemmas. For example, when does chemist's moral responsibility as a member of the larger human community take precedence over obligations to an institution or country? In recent years, chemistry increasingly became involved in cases that do not fit the simple scheme of doing/preventing/undoing harm through chemicals, or at least the public awareness has shifted to a broader scope of ethical issues and values. Global environmental issues, such as climate change and the exploitation of limited resources, have taught us that every harm and its remedy affect different

populations and different generation unequally, which raises the issue of global and inter-generational justice to which there is no technical fix. Recent attempts to create lives in the laboratory are not seen as threats to one's health but as ways to undermine received cultural value.

Similarly, the public debates on where a sequence of human DNA can be protected by patent law or does not refer to physical harm but to a possible erosion of values. Moreover, as chemistry have the potential of changing the human mind through drugs, both temporarily and enduring, it undermines the notion of what a normal human being is if enhancement drugs become regularly available. The above are various ethical issues which need to be tackled as challenges through the study of chemical education in various institutions

These issues arise from chemistry's position in the middle between the theoretical and the practical, a science concerned with molecules that are of the right size to directly affect human life. Many of the issues are raised by the central activity of chemistry—synthesis. Chemists make thousands of new substances each year. Many are beneficial, but others are threats. Since the development of the chemical industry in the nineteenth century, chemistry has contributed to the deterioration of the environment but has also helped to reduce pollution. According to Abubakar (2013), he asserts that it becomes expedient that in the teaching and learning of chemistry education teachers have to bear in mind the implications or the effects of the substances so produced to mankind now and in the future. However, the integration of ethical considerations on chemistry education and practice will be useful to divide the case in three groups according to the dimensions of the ethical issues. These most prominent cases yet to be discussed, cover almost all fields of chemistry, although there have been different emphases at different times

Ethics in the Laboratory

Chemistry is rooted in the laboratory where ideas, knowledge, and technique come together. Getting a chemical reaction to work satisfactorily, in a reasonable amount of time, and with a good yield can be tricky (Kovac, 2018). A classic volumetric analysis requires careful use of glassware: volumetric flasks, pipettes, and burettes. Accurate weighing is an essential part of chemistry.

One of the core principles of science, and an important moral rule, is to describe experimental procedures completely and carefully so that another person can reproduce the results. Anyone who has tried to reproduce an experiment described in the chemical literature knows that this is easier said than done. Sometimes, an experiment cannot be reproduced because it really did not happen that way; the results are fabricated. Usually, however, the reasons do not involve scientific misconduct. Often experimental details are unintentionally omitted due to carelessness or because they seem obvious or are part of the usual routine of a particular research group or because of poor record keeping.

Ethical Considerations on Chemistry Education and Practice

A more ethically interesting reason is that some people are better at doing experiments than others. They are more careful or just seem to have a knack for making things work. For example, apparently the only person who could get Robert Boyle's air pump to work properly was the man who made it. In chemistry, some people just have "magic hands". The difficult ethical issue is the following one. Can we call an experiment reproducible if the only people who can get it to work properly are those with magic hands? What is the responsibility of the original research group to ensure that the procedure can be reproduced by an average chemist? This is a problem in all of laboratory science, but it is perhaps most important in chemistry which involves as much art as science. This particular issue therefore has to be carefully tackled through the process of teaching and learning of Chemistry education in schools. According to Carlson and Hudlicky (2012) some related issues have been recently discussed in malpractice in organic synthesis. (The authors distinguish malpractice from scientific misconduct). The authors further listed three classes of improper practice in organic synthesis: improper experimental protocols, improper methods used in characterization of compounds, and the lack of proper citations to previous work. Probably the greatest concern is improper characterization which can lead to errors in structural assignments.

The primary method used is NMR, a powerful tool, but not always definite. Nuclear Magnetic Resonance (NMR) spectroscopy is an analytical chemistry technique used in quality control and research for determining the content and purity of a sample as well as its molecular structure, (Nanalysis, 2019). Example; for unknown compounds, NMR can either be used to match against spectral libraries or to infer the basic structure directly. Then, for known compounds, NMR can analyze mixtures containing known compounds. The basics of NMR include: Chemical shift and Spin-spin coupling, (Nanalysis, 2019). When syntheses are carried out in micro scale, it may be impossible to obtain some of the classic data, such as a percent composition by combustion analysis, or even a good melting point. Without a definitive characterization of the product, the results may not be trustworthy.

Analytical chemistry also presents ethical challenges in the laboratory. As discussed above, many synthetic commercial chemical products contain impurities, some of which are dangerous. Products derived from natural sources are usually complex mixtures. Sea salt, which has recently gained popularity in gourmet cooking, is mainly sodium chloride, but also contains small concentrations of other cations and anions. Beverages such as coffee, tea, or wine can contain hundreds of components in widely varying concentrations. The task of the analytical chemist is to determine what components are present, which involves separation and identification, and then to determine how much is present. Knowing what is present is an important question in product safety for example. Chemistry education provides opportunities for the learners and users of the above products to be mindful of their toxicity in their uses in their various homes or environments.

There are several aspects of the analysis process that can raise ethical questions. One is the problem of detection limit. All chemical analyses have a lower limit of detection so the question of whether a trace component is part of a mixture can only be answered by saying that, if it is there, it is present in a quantity less than the detection limit. If the suspected contaminant is harmful, this can put the analyst in a difficult position. Suppose the analytical chemist is called to testify in a lawsuit where the crucial issue is whether a particular contaminant was present. The question from the lawyer would be, "Was substance A present?" In an adversary proceeding, the expected answer is either "yes" or "no." But the professional ethics of science require a more nuanced answer like, "It was not detected, but the method used can only detect concentrations greater than X." Although the analyst could answer "no" without committing perjury, such an answer would not be scientifically responsible.

Another issue is chemical calibration. Quantitative determination of the concentration of a substance often requires a chemical calibration using known amounts of the substance to be determined, which may have to be synthesized, in a matrix that is sufficiently similar to that of the unknown sample. The question of what is sufficiently similar is a matter of judgment and, as some people argue scientific judgments have both a technical and a moral component. Depending on the circumstances, getting it wrong can have serious consequences.

Chemical Weapons and Other Dangerous Substances

Chemical education has a crucial role to play in this regard because of the enormous consequences of the productions and use of such weapon and substances in theaters of war. The educators have to explain the various implications to the learners which they have to carry along to the society. They have also to make the producers of such weapons to be aware of the ethical issues involved in applying such substances and weapons to human beings. A very difficult ethical question for chemistry educators is whether to conduct research on chemical weapons. These substances are banned under the Chemical Weapons Convention of 1993, which has been signed by nearly every country in the world including the United States. The Chemical Weapons convention prohibits the development, production, stockpiling, and use of chemical weapons. It also mandated the destruction of all chemical weapons and destruction or conversion of all production facilities by 2007. Progress in accomplishing this latter goal has been delayed, but most of the stockpiles of these weapons have been destroyed and the production plants deactivated. In recent years, there has been less fear of the use of chemical weapons in wars between nations, but more concern about their production and use by terrorist organizations.

Research on chemical weapons continues, for example at the U.S. Army Medical Institute of Chemical Weapons Defense (Chemical Weapons Defense, 2013). Of course, much of this research is classified, but even defensive research might involve the development of new chemical weapons with the goal of finding appropriate counter

Ethical Considerations on Chemistry Education and Practice

measures. There is also research on what are being called non-lethal chemical weapons which include anti-traction agents and malodorants or other novel chemical agents (Guardian, 2008). There is some question as to whether these new non-lethal agents violate the Chemical Weapons Convention because it is not known whether they are toxic at high doses. Malodorants might also have adverse effects other than toxicity, adverse psychological effects for example. The broader ethical question as to whether scientists should engage in war-related research is complex, but chemical weapons raise that question in stark terms (Kovac, 2018).

Environmental Pollution and Green Chemistry

Another important area ethical considerations of chemical education are vital is in environmental pollution and green chemistry. Whatever the substance to be made, there are ethical issues related to the method of production. Since its inception, the modern chemical industry has been responsible for widespread environmental degradation (Bensaude-Vincent & Simon, 2008). Well publicized accidents such as the disaster in Bhopal, where thousands of Indians were poisoned by methyl isocyanate leaking from a Union Carbide plant, have added to the negative public image of chemistry.

There are practical, economic, and ethical reasons to improve safety at chemical plants and to reduce the environmental impact of the production of chemicals. The effort to make chemical production more environmentally benign is usually called Green Chemistry. Through chemical education chemical industries will adopt cleaner and greener methods of production if they make economic sense or are required by government regulation or severe public pressure. The question is who will develop the new chemistry. Certainly, some of the research will take place in industrial laboratories, in the research universities. Where people are taught, values are formed” (Hoffmann, 2012). The ideal of shared fate individualism suggests that chemists in research universities should focus more of their research efforts on green chemistry: atom and energy economy and benign solvents.

The current environmental crisis raises other scientific and ethical questions. First is environmental remediation, cleaning up the messes that industrial chemistry has made over the past century and more. A second one is what has come to be called sustainability, finding ways to use renewable resources rather than petroleum as both fuels and feed stocks. There is an obvious link to global warming, reducing the production of greenhouse gases. There has been progress; the development of the modern catalytic converter has done much to reduce air pollution, but much more needs to be done. Bensaude-Vincent and Simon (2008) argue that we need a new chemical culture in relationship to the environment, one that proscribes the causes of dangers to human and environmental health.

Conclusion

Throughout its history, chemistry has made significant contributions to human progress but with those successes have come problems, especially problems of environmental pollution. Synthetic chemicals have become a major part of our lives. The circumstances of today's world provide both scientific and ethical challenges for chemistry. Of course, chemists face the same ethical challenges that all other scientists, and indeed all human beings must confront. Our future depends on our willingness to ask and answer these crucial ethical questions.

These are areas Chemistry education is expected to address as its core contributions towards utilization of the importance of Chemistry to mankind without jeopardizing the existence of man in his environment. More than the other sciences, chemistry is centered in the laboratory so it is important that laboratory practice adhere to the highest professional and ethical standards. Finally, the chemical profession through the professional societies needs to reexamine the codes of ethics to ensure that they respond to the practical and ethical challenges of today's world in which synthetic chemicals touch essentially every part of our daily lives. Ethical considerations opt that no human rights are violated, and research being conducted has no hidden agenda. The paper concluded by advocating for integrating ethics into chemistry curricula as this would eventually lead to educating future generations of responsible chemists.

References

- Ababio, B. (2013). Chemistry education and entrepreneurial development in Nigeria: Issues and challenges. *Journal of Quality Education. Isah Kaita College of Education Dutsenma vol. 2 (1)*, 107-114.
- Abubakar, T. (2013). Role of education in the realization of Nigeria's transformation agenda. *Farfaru Journal of Multi-Disciplinary studies: Special Conference Edition*, 8(8), 0795 – 4597.
- Allison Academy. (2021). Role of society in child development. Retrieved December 22, 2021 from <https://www.allisonacademy.com-role-of-society-in-child-development>.
- American chemical society (2012). The chemical professions' code of conduct. Retrieved July 29, 2013 from <http://www.acs.org/content/acs/en/careers/profdev/ethics/the-chemical-professionals-code-of-conduct.html>
- Australia Law Reform Commission. (2021). Essentially Yours: The protection of human genetic information in Australia (ALRC Report 96).

Ethical Considerations on Chemistry Education and Practice

- Avi, H., & Eilks, I. (2015). Relevant of Chemistry education: From theory to practice. Sense publishers. Retrieved October 10, 2018 from <https://www.sensepublishers.com> .
- Beauchamp, T. L. & Childress, J. F. (2009). *Principles of Biomedical Ethics*, Oxford & New York: Oxford University Press, seventh edition.
- Bensaude-Vincent B. & Simon J. (2008). *Chemistry: The impure science*. London: Imperial college press.
- Bhasin, H.,(2020,October 30).What are ethical considerations in research? Retrieved December 23, 2021 from www.marketing91.com/ethical-considerations-in-research.
- Carlson R. & Hudicky T., (2012). On hype, malpractice, and scientific misconduct in organic synthesis. *Helvetica Chemical Acta*, 95, 2052 – 2062.
- Chemical Weapons Defense. (2013). Research for the Warfighter. Retrieved January 5, 2015 from [http://chemde.apgea.army.mil/...](http://chemde.apgea.army.mil/)
- Guardian (2008). Us weapons research is raising a stink. Retrieved July 1, 2013 from <http://www.guardian.co.uk/science/2008/jul/10/weaponstechnology.research>.
- Hoffmann, R. (2012). Ethics and science. In: Kovac J., Weisberg, M. (Eds.) *Road Hoffmann on the philosophy, Art, and Science of Chemistry*. New York: Oxford, pp. 360 – 376.
- Kovac, J. (2018). *The ethical chemist: Professionalism and ethics in science*, New York, NY: Oxford University Press, second edition.
- Lawrie,G. A., Graulich, N., Kahveci, A., & Lewis, S.E. (2021). Ethical statements: a refreshing of the minimum requirements for publication of chemistry education research and practice. *Chemistry Education Research and Practice*, 22, 234-236. Doi:10 1039/DIRP90003J.
- Muoneke, N.M., Asagha, E.N., & Muoneke, C.U., (2021).Chemistry education and national development commission for colleges of education minimum standards: An analysis of trends, challenges and development of cloud-based applications. *A Multidisciplinary Journal of Academic Excellence*, 21(1),
- Nanalysis (2019).What is NMR spectroscopy and how does it work? *Nanalysis.com*.

Mary Nneora Muoneke and Vitus Chidozie Muoneke

O'Neill, J., & Bourke, R., (2010). *Education teachers about a code of ethical conduct*. *Ethics and Education*, 5 (2), 179-192.

Pakhshi, A. K., & Rarh, V. (2012). Chemistry education in the 21st century: Challenges and opportunities. *Sciences Reporters*.

Rachels, J. (2012). *The Elements of Moral Philosophy*, New York, NY: McGraw Hil, 7th edition.

Schummer, J. (2018). 'Why Chemists Need Philosophy, History, and Ethics', *Substantial*, 2(1), 5-6.

Schummer, J., & Borsen, T. (2021). Ethics of chemistry: Meeting a teaming need. DOI: 102.89.1.104. www.worldscientific.com.

Simon, J. L. (2018). Nature review. Retrieved October 20, from www.nature.com/subject/chemical-education