Biotechnology and Bioethics in Engineering Education

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ABSTRACT

Biotechnology offers a great deal of opportunities for human to improve the health and quality of life using new medicines and biomedical devices. However, this technology brings a number of questions and concerns about the social, cultural, moral, legal, and ethical implications of the technology. The main problems are related to the fundamental concepts, principles, and theories addressing those issues arising from clinical practice, medical and biological research, resource allocation, and access to biomedical technology. Bioethics deals with all of these issues and provides possible solutions in the field. In the present bioethics study, we will provide a detailed report of the implications of biotechnology and bioethics, which may be useful for training and protecting undergraduate and graduate students, as well as scientists, doctors, nurses, engineers, policymakers, and regulators working in the field.

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1. INTRODUCTION

1.1 General Background

Biotechnology is the study and manifestation of living bodies or their components (e.g., molecules, organs, cells, and tissues) in order to improve their living conditions [1]. This emerging field is closely related to ethics, science, and modern scientific knowledge. Bioethics is the consideration of ethical challenges arising during the research and development of biotechnology and medical science [2]. It is basically "*the study of the moral and social implications of techniques resulting from advances in the biological sciences"* [3]. Bioethics also involves issues related to the morality of various biological, biotechnological, and medical practices and procedures [2]. Since the entities have moral issues that are significant, they deserve to be the object of moral consideration [2].

Although bioethics laid down its foundation in the 1990s, it actually has a long tradition [4].

Greek Hippocratic ethics was the first detailed acknowledgement of professional responsibility requiring physicians to not harm their patients [4]. In the early 1960s, bioethics took on another dimension and moved beyond the classical ethics issue in medical science and biology to promotion of a civilized doctor/patient relationship. At that time, bioethics developed into an aesthetical professional discourse and discipline comprising all ethically related issues in medical science and technology. It began to encompass other ethical issues involving animals, the environment, and cultured cells and their use during research, development, and application [4].

For a few years now, the numbers of self-described progressives and progressive organizations have increased [5]. Advancement in the early twentieth century faced economic and political issues that threatened values and the way of life [5]. In bioethics, the interest is typically in formulating policies and practices in the life sciences. Joseph Fletcher wrote a book in 1954 called *Morals and Medicine* [2]. At that time, many people raised questions about abortion, euthanasia, war, capital punishment, and animal rights, and debated these issues in many forums [2]. Recent development in the field of medical science has also raised questions about the selection of people for dialysis, heart transplants, organ transplants, etc. [5]. Many institutions and centers of bioethics have been established in many countries around the globe. In 1969, the Institute of Society, Ethics and the Life Sciences was founded in the United States [2], and several other countries have established their own national bioethics associations. The number of journals and conference proceedings published on bioethics has been rising every year.

Today, modern society makes rapid decisions about science and technology. These decisions affect all living organisms, the environment, and international policy [2]. In making decisions, some basic ethical and moral principles must follow rules, regulations, and principles. Four fundamental principles are related to bioethics, including confidentiality, beneficence, justice, and autonomy. The principle of *confidentiality* means that whatever is revealed in confidence should be kept confidential [2]. The principle of *beneficence* refers to development and advancement in technology without harming any entity and without causing any injustice. The principle of *justice* involves the benefit and risk of new technology that should be shared by all parties. The principle of *autonomy* is related to the freedom of each individual to control his/her life and rights. Ethical behavior demands the ability to understand the consequences and to make wise decisions about one's action [6]. Since the area of bioethics encircles many issues related to ethics, environment, life science, and medicines, this study will address those issues clearly and understandably.

1.2 Bioethics Today

Recently, bioethics has been concerned about new advancements in medical fields, such as international collaborative clinical research, organ transplants, aging, human lifespan, AIDS, genomics, cloning, and stem cell research and development [5]. It also provides additional information on animal bioethics, genetics, genetically modified foods and crops, reproduction, environmental ethics, and medical developments under the three headings of animal, human, and agriculture. A wide variety of disciplines in medicine, pharmacy, biology, and manufacturing discuss these problems/concerns associated with bioethics and its recent developments using online sources and media [5-11] in the following ways:

- Updating weekly news items, and announcing current and future events in bioethics.
- Disseminating information about comprehensive research studies and findings.
- Providing links to all bioethics sites around the world.
- Organizing regional, national, and international conferences and seminars.
- Providing governmental and legislative news.
- Archiving all rules and regulations for public and scientific use.
- Training undergraduate and graduate students, as well as doctors, nurses, engineers, scientists, and other workers in the field.

1.3 Goals of Bioethics

In the mid-1990s, the World Health Organization (WHO) suggested some specific goals for bioethics research, development, and teaching, to ensure that principles of medical ethics are recognized and applied globally. These specific goals should also be part of medical research and education at undergraduate, graduate, and postgraduate levels worldwide. The following are some of the goals associated with bioethics [2]:

- To understand issues related to biotechnological, biology, and medical advancement.
- To raise questions about the nature of ethics, value of life, and significance of all living organs in the planet.
- To address issues of public policy, and the direction and control of science.

The cognitive, behavioral, and attitudinal goals related to imparting theoretical and conceptual bioethics knowledge and analytical abilities as a standard to realizing and managing ethical issues of biotechnology are provided below [2]:

Cognitive Goals:

- To increase sensitivity to awareness of ethical values in medical practices.
- To encourage and promote critical reflection on individuals' own personal and professional values.
- To teach and practice the skills of ethical reasoning and analysis.
- To provide workers with an approach for clinical decision-making.

Behavioral Goals:

- To bridge the gap between knowledge of ethical principles and reasoning in clinical practice.
- To facilitate self-expression and shared decision- making by patients.
- To share positive and negative news with patients carefully.
- To obtain consent or refusal of treatment with the patient and his/her family.
- To find out when it is necessary to withhold information from a patient or to break confidentially.

Attitudinal Goals:

- To describe idealism and integrity.
- To determine accountability, willingly engage in free discussion, and always be prepared to examine circumstances from the patient's point of view.
- To share sympathy and compassion.
- To be prepared for any disagreements.

1.4 Challenging Aspects of Biotechnology and Bioethics

Initially, ethics and moral characteristics were related to human-human interactions. Humans dealing with non-humans was regarded as ethically neutral [1]. With the advancement of new technologies, ethical values must cover a broad spectrum of environmental, non-human, legal, and international collaborative issues. New technology also focuses on natural resources, and environmental and global issues. Prior to technological development, it was assumed that natural resources were abundant and would always exist. Ethical evaluations of biotechnology must consider natural resources and global contaminations [1]. These issues can lead to new challenges, such as renewal energy resources stemming from ethical concerns for the environment [1]. Some of the bacteria and viruses used in energy-related research and development are also part of these challenges [12].

2. ISSUES IN BIOETHICS

Although biotechnology has been widely accepted in a number of applications, several uncertainties bring bioethics into biotechnology research, development, and education in order to seek and examine the potential risks and rewards of the applications of biotechnology-related materials, devices, and practice, as well as societal, economical, moral, health, and other broader human implications of the technology [12]. The following bioethics issues (e.g., morality, religion, health and safety, social and philosophical, environmental, educational, and other legal issues) involving biotechnology may be very useful for training and protecting undergraduate and graduate students, as well as scientists, doctors, engineers, policymakers, and regulators working in the field.

2.1 Bioethics and Morality Issues

Morality is a general attitude and standard behavior, while ethics is the discipline and systematic enquiry into the nature of morality [3]. Morality is an innate and defining characteristic of humans [3]. We believe that certain types of behavior are right and others are wrong, so we should pursue the right and avoid the mistakes to create a better society [3]. It does not determine what we should do in all circumstances, or that we should always do what we believe in—complete moral perfection and excellence are beyond all of us [3]. In contrast, it is generally expected that every human being is well aware of moral dimensions and acts accordingly.

2.2 Bioethics and Religious Issues

Some believe that ethics may have had its origins in the dispositions inherited from non-human species, while other believe that ethical behavior has a different kind of origin and is related to religious concepts [3]. In the early ages, religion was one of the major factors involved in decision making for a particular society. Different religions, such as Christianity, Judaism, and Muslim, have their own ethical stances, and developed their own rules and guidelines on how to deal with issues within their viewpoints and faiths. Also, a large number of people are agnostics or atheists, so the possibility of meaningful dialogue between different peoples or cultures may not take place if religion is the only criteria or concern. Other religions and cultures may have different approaches on the same topics, as well. As a result, bioethics can vary based on the faith and cultural diversity of the religious issue.

2.3 Bioethics and Safety Issues

It is known that several biotechnology-related products are safe and have been used for various applications to improve the quality of life; therefore, it is important to clearly differentiate those products or practices that cause disease or health concerns. Safety is one of the most considered issues in biotechnology and bioethics because inevitably, there will be human experimentation to validate the various approaches, which is the riskiest step of this kind of study [13]. Some effects can occur immediately, while others can take several months or years. For example, many people are raising their concerns about the safety issue of biotechnology and genetic engineering. Scientists have been considering this issue for more than a decade. A committee of the National Academy of Sciences reviewed the issues on genetically engineered DNA or R-DNA [7]. Their suggestions indicate that "there is no hazard either in use of the R-DNA technique or in the transfer of genes between unrelated organisms" and that "the risks associated with the introduction of R-DNA engineered organisms are the same kind as those associated with the introduction of unmodified organisms." The committee also concluded that R-DNA is a safe new technology for modification of organisms for all living species [7].

Containment during experimentation is crucial to safety. Physical containment associated with biological containment makes the issue even more complicated [12]. However, it is believed that during the last ten years, scientists have gained enough experience in handling unsafe materials, processes, and practices. Scientists have shown that containment cannot survive in the harsh conditions of the human body or the external environment. Some people have raised concerns that biotechnology would probably increase the risk of biological warfare and is an issue that requires continuous vigilance [7]. Improved genetic tests can be used to track down criminals in assault cases based on the uniqueness of their DNA. Genetic counseling can provide advice on heritable diseases, and genetic screening of workers in possible risky industries is being considered. DNA probes also provide breakthrough knowledge in early diagnosis of disease [7].

Recent studies have shown that when certain nanomaterials, which differ in surface area, size, shape, surface charge, and energy, and compounds interact with human and animal cells or organs, they can damage or kill those cells or organs, block blood flow, and cause serious deadly diseases [15]. Some diseases associated with nanomaterials include asthma, bronchitis, lung cancer, Parkinson's disease, Alzheimer's disease, Crohn`s disease, heart disease, and colon cancer. Nanomaterials can also affect the quality of air, water, and soil and thus cause public

health concerns [16]. Understanding their causes and mechanisms will more likely lead to finding cures for the deadly diseases associated with nanomaterials used in biotechnology.

2.4 Bioethics and Societal Issues

Decisions on biotechnology and bioethics frequently influence our daily lives. This category of bioethics includes more important aspects of ethical behavior that cannot be addressed easily by scientists, policymakers, and the public. Examples could include openness of information sharing; risk mitigation for patients; costumer/patient convincement; and local, national, and international investment [14].

Biotechnology has made it possible to detect, and in some cases treat, several diseases, such as sickle-cell anemia, Tay-Sachs disease, diabetes, and cystic fibrosis [7]. Following initial concerns, biomedical engineering could give rise to infectious organisms, the spread of which would be difficult to maintain. A stringent set of guidelines and rules was drawn up by many governments and leading scientists in the mid 1970s to regulate research and development in this field [7]. While it is not possible to completely eliminate the risk of a biomedical engineering accident, experience over the last ten years of research has indicated that the chances of constructing a disease-producing organism by accident are considerably small. This is because such pathogens require an extremely complex set of distinct characteristics and are effective only when all conditions are present [7].

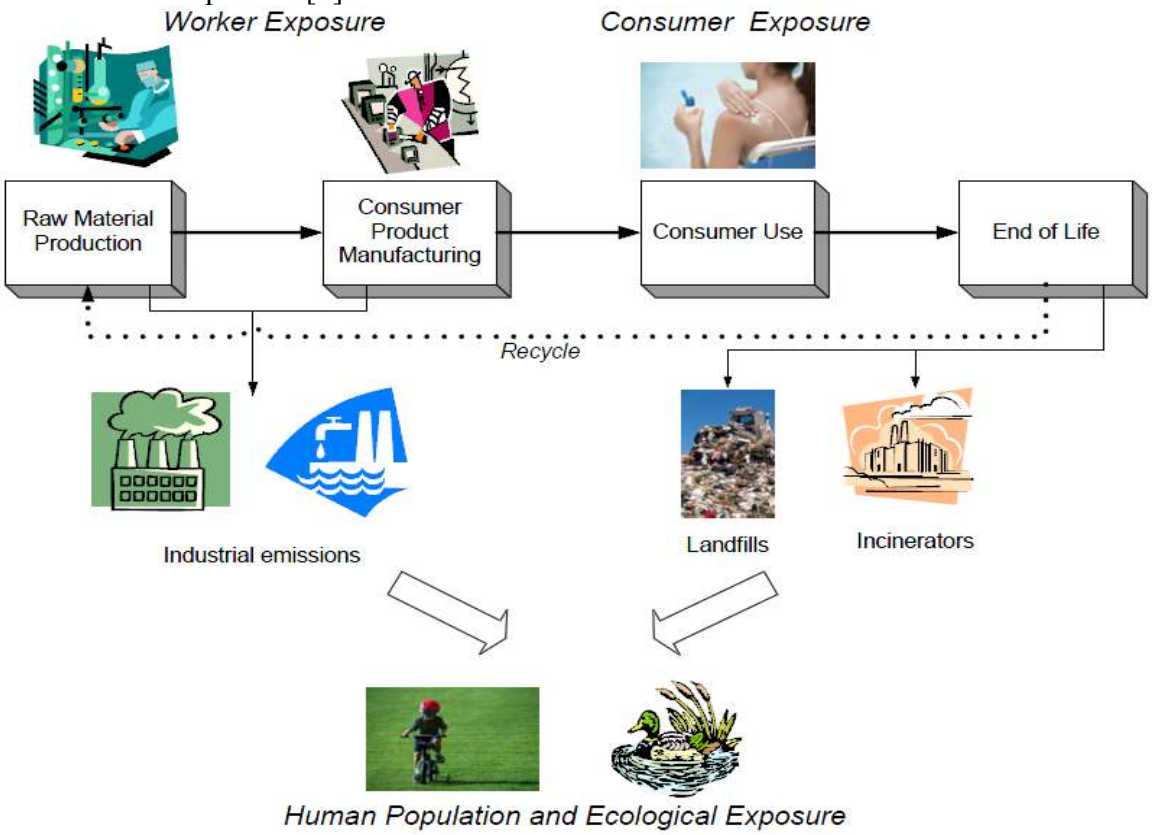

Figure 1: Exposure of humans and the environment to nanomaterials at different stages of a product's life cycle.

Some nanoscale materials, such as nanoparticles, nanofibers, nanocomposites, nanotubes, and nanofilms, have been used in biomedical applications for more than ten years [22], which has created some nanoscale pollution. Nanoscale pollution is a generic name for all the waste generated by nanomaterials and devices during the manufacturing process. This raises a serious concern about the limitations of an economic cost-benefit analysis [17]. During manufacturing, transportation, and waste disposal processes, nanomaterials can contaminate the air, water, soil, and food supply (e.g., vegetables, fruits, and animal products). Nanoparticles can also remain airborne, traveling hundreds of kilometers, and penetrate human, animal, and plant cells, thus causing many known and unknown side effects. Most human-made nanomaterials do not appear in the environment, so living organisms may not have an appropriate immune system to deal with these nanoscale products [17]. Figure 1 shows the exposure of humans and the environment to nanomaterials at different stages of a product's life cycle [18]. This figure clearly defines the life cycle of nanomaterials from their beginning as raw materials to their disposal in landfills.

2.5 Bioethics and Legislative Issues

Many countries consider the ethics of biotechnology research, development, and applications [12]. Some countries have already established research guidelines and rules for working on embryo transplantation, embryo research, surrogate motherhood, and other issues [7]. Legal problems have already emerged regarding the laws relative to different biotechnology products and practices. For example, in 1980, a U.S. court overturned existing practice and ruled that genetically engineered microbes may be patented [7]. Similar laws were also passed for cloning and stem cell research and development. Reproductive cloning is a technology used to generate an animal that has the same nuclear DNA as another currently or previously existing animal. Dolly the sheep, first animal created by reproductive cloning technology, lived six years [21]. Cloning human embryos for therapeutic purposes was made legal by an amendment to the Human Embryology Act in January 2001. However, cloning humans for reproductive purposes still remains illegal and is punishable by a ten-year prison sentence with unlimited fines [21].

2.6 Bioethics and Educational Issues

Biotechnology offers amazing benefits to human and animal life and to the environment, but it can lead to educational consequences. Research and development on biotechnology and bioproducts have been growing rapidly for more than two decades; however, educational progress has not been as rapid as technological development. In other words, technical training is not sufficient for individuals working in the field; parallel training, which will be useful for societal and ethical implications of the technology, is required [18].

Providing interdisciplinary and multidisciplinary training of bioethics for students and scientists, as well as doctors, engineers, medical practitioners, social scientists, workers, and lawyers in every discipline, will offer great benefits [19]. This training can be accomplished through new class development, seminars, conferences, invited talks, and other individuals who are experts in biotechnology and bioethics. For undergraduate and graduate students who are preparing themselves for careers in bioscience and biotechnology, whether as MDs, nurses, biologists, chemists, physicists, or engineers, new courses providing a needed focus on bioethics should be

introduced. These courses should be taught by different professors from various departments and should be mandatory for students working in the field of biotechnology.

In addition to these measures, other educational actions may include television, media, and online news to inform students and the public about biotechnology and bioethics. A departmental website should be prepared to continuously upload and display the most-current information. Government agencies, such as the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), the National Institutes of Health (NIH), the Department of Health and Human Services (DHHS), and private medical and pharmaceutical companies should have financial support and actively participate in the educational issues of bioethics.

2.7 Bioethics and Other Issues

Even though modern bioethics is a new field of study, it also deals with many other issues, including xenotransplantation, surrogacy, stem cells, HIV/AIDS, genetic testing, genetic engineering, euthanasia, end of life issue, embryo adaption, and bioethical principals [19]. Xenotransplantation involves transplanting living cells, tissues, or organs from one species into another, while surrogacy involves a woman (the surrogate mother) carrying a child for someone else, usually an infertile couple or sometimes a gay couple. In addition, other concerns and questions related to biotechnology and bioethics have not been completely addressed yet [20]:

- Should terminally ill people have the right to control their own death?
- Would legalizing assisted suicide relieve families of the burden of caring for a terminally ill relative?
- Would legalizing assisted suicide lead to euthanasia?
- Should doctors be prosecuted for assisting in the suicide of a terminally ill patient?
- Should we encourage wider use of genetic screening?
- Should we enact privacy rules controlling the release of genetic test results to employers or insurance companies?
- Is discrimination an inevitable result?
- Can these tests be trusted to be accurate?
- Should healthy people take medical action as a result of genetic testing results?

Overall, biotechnology and bioethics pose many challenges to external legal and regulatory issues, and these challenges will continue as technology advances. A variety of biodevices and products produced by biotechnology and nanotechnology will require new rules and regulations. Many government agencies, such as NSF, FDA, EPA, and NIH, will have their own regulatory approaches, all of which will improve the safe practice and use of biotechnology and its products in the future.

3. CONCLUSIONS

Biotechnology is an emerging technology and is a useful tool in the advancement of health and science. In this study, biotechnology, bioethics, and their impacts on our daily lives have been discussed. Different issues related to professional ethics, morality, legal limitations, religious

aspects, and safety were also outlined. Some biotechnology products and practices are completely safe, while others are highly toxic and harmful, causing serious diseases to humans, as well as animals and plants. Bioethics deals with all of these issues in order to create a safer work environment for students, scientists, engineers, doctors, nurses, and other individuals participating in biotechnology research, development, and education.

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