Summary

This paper outlines the issues in ethics and bioethics in engineering. The significance of and key differences between ethics and bioethics are first explained, followed by a general ethical problems encountered in engineering, along with notable bioethical issues occurring in several branches of medicine. Finally, the importance of applying ethics and bioethics in engineering is emphasized, with the primary goal of acting for the benefit of the individual and the humanity in general, while simultaneously striving to act respectfully towards and in harmony with nature and natural laws.

Key words: ethics, bioethics, engineering, biomedical engineering

1. Introduction

Current rate of technological development allows for further advances in science and interdisciplinary areas combining different fields of science. Among these interdisciplinary areas, biomedical engineering and bioengineering stand prominently, and the development of these two areas opens new questions within ethics and bioethics. Engineers should be aware of the purposefulness of their products and how much is something beneficial for the community or not, as well as how their product will contribute to the society. Engineers should have the ability to think critically and continually re-examine themselves, as well as the impact of technology on social, cultural, ethical and moral aspects of society. All of the above opens up a platform for discussion. However, before the discussion can be initiated, it is necessary to understand the basic concepts in ethics and bioethics, and what are the areas of special interest in the field of biomedical engineering and bioengineering in the context of ethics and bioethics [1].

2. Ethics and Bioethics

Ethics is the branch of philosophy which is concerned with living well, being a good person, doing a right thing, getting along with other people and wanting the right things in life. Basically, ethics is a system of moral principles. These moral principles are actually rules of behaviour that are societally accepted as morally valuable. In this way, ethics helps people to realize what is right to do and what is not, and to behave in the best possible way, which is embedded within the rules themselves. The freedom of thought is especially emphasized in a democratic society, along with the need for constant re-examination whether certain action is ethical or not, and which type of action is more appropriate among different alternatives.

Understanding and possessing ethics is necessary for individual’s successful integration into the society, regardless of tradition or culture of the society in question, its practices and institutions. Societal traditions, practices and institutions are the ones that need to assess themselves within ethical standards, but also to bring forth the rules and expectations of the people living within the particular community, and society in general. Ethics has a social, but also a personal dimension, and these two dimensions are sometimes difficult to distinguish in theory and in practice. For example, moral judgment is the product of society, but also one of the most important personal characteristics of a man. Ethics offers a number of beneficial tools to use when reflecting upon a moral issue [2].
Bioethics is a branch of ethics that deals with ethical issues in natural sciences such as biology and medicine. Conversely, the development of technology has propelled several interdisciplinary fields such as biomedical engineering, biotechnology, bioengineering, and those areas have particularly contributed to a number of ethical questions, and to the re-examination of the very term “bioethics”. Bioethical analysis is intended to help people with decisions about their behaviour, and can also be helpful in dealing with policy questions that governments, organizations, and communities might face when they consider how best to implement new biomedical and bioengineering know-how and innovations [3].

Bioethics and ethics are mutually related concepts (Fig.1.), and bioethics cannot be investigated without proper understanding of ethics and moral principles.

Fig.1. Ethic and Bioethic worldcloud

3. Engineering Ethical Issues

Being an engineer is a very responsible occupation. An engineer is, first and foremost, a creator: he/she designs new products and services which should improve the quality of human life. Recent technological advances have initiated an exponential growth within every major branch of science, especially within natural and technical sciences. On the other hand, globalisation and intensified market competitiveness have contributed to the increased pressure imposed upon engineers to continuously improve upon existing products and services and to create more advanced ones within shorter time frames. Furthermore, new interdisciplinary fields have been developed, such as bioengineering and biomedical engineering.

The emergence of these new fields has heralded a multitude of novel issues within ethics, and the related branch of bioethics. However, lacking ample time to re-consider these issues, while also being subjected to the requirement of ever faster profit generation, engineers frequently avoid adhering to ethical principles, and to re-examine their actions. There is a number of ethical guidelines that mandate responsible behaviour in engineering. Within each of their activities, engineers should respond to questions such as: How beneficial is their current effort to the society as a whole? What are the risks of technology or the particular product?
How would that product affect the environment and what would be its overall effect on flora and fauna? Does that product or process contribute to the improved quality of life? Is it in accord with natural laws?

However, today’s world, characterised by ubiquity of information and desire for instant success, is riddled with engineers who falsify their reports and plagiarise other people’s work, who design product and services that devastate the environment, or are specifically designed to destroy human, animal and plant life. Furthermore, contemporary accelerated lifestyle has also contributed to the banalisation of knowledge and abandoning of true moral values, which is also true for the Republic of Croatia. In particular, instead of being content with gaining knowledge, using it for the benefit of the society, and passing it onto new generations of engineers and scientists, today’s experts frequently abandon ethics, morality and love of other human beings, which manifests in illicit and immoral gaining of professional degrees and employment, merely to advance their social status and increase their financial gains [4].

4. Biomedical Engineering and Bioengineering Ethics

In recent years, technology development has created new moral dilemmas, spawning an increased interest in the field of bioethics, which affects engineers in biomedicine, physicians and other health-care professionals, and society in general. Biomedical engineering (BME) applies engineering principles and design concepts to medicine and biology with the aim of improving current and envisioning novel healthcare practices, thus also working towards closing the gap between engineering and medicine (Fig. 2). In particular, it combines the design and problem solving skills of engineering with medical and biological sciences in order to advance health care treatment, and to improve diagnostic tools, patient monitoring, and application of therapy. Biomedical engineering has only recently emerged as its own field of study, in comparison to many other engineering fields and biomedical engineers differ from medical practitioners, and are similar to other engineers, in that they are involved in research for and development of new technology, and do not engage in the study, diagnosis and treatment of patients [5].

![Fig.2. Biomedical engineering world cloud][6]

On the other hand, bioengineering focuses on the engineering of biological processes as well as biomedical engineering, but unlike biomedical engineering, bioengineering focused on systems in general, which includes not only biomedical engineering but also agricultural engineering, food engineering and biotechnology (Fig.3). In other words, biotechnology is the study of living bodies such as molecules, organs, cells and tissues in order to improve their living conditions and improve quality of life.
Currently there is no distinct academic field of biomedical engineering and bioengineering ethics, simply because biomedical engineering and bioengineering are in theirself a new field. Ethical issues in biomedical engineering are currently being studied within frameworks of bioethics, medical ethics and engineering ethics, as target fields of biomedical engineering application. Professional ethical issues in biomedical engineering are often different from the ones traditionally discussed in these fields.

Consequently, bioengineers may often lack adequate training in facing moral and ethical problems, which may include conflicts of interest, allocation of scarce resources, research misconduct, animal experimentation, and clinical trials for new medical devices [7].

![Fig. 3. Bioengineering](image)

5. **Cellular, Genetic, Neural and Tissue Engineering**

Stemming from the research in biology and medicine, new branches of cell, tissue, neural and genetic engineering have been established within the field of engineering. All of the aforementioned branches have contributed to extraordinary discoveries, which have resulted in improved quality of human life, as well as to the improved care for plant and animal life, and, consequently, for the environment as a whole. However, the aforementioned engineering branches have also encroached into ethics and bioethics, and have initiated a number of polemics within these fields. Obviously, the greatest polemics have been caused by animal and human cloning, interspecies hybridisation, growing of living creatures under artificial conditions and similar. All of the above issues represent major challenges in the field of ethics.

Tissue and cell engineering are two narrowly associated branches of bioengineering, which are focused on growing of cells and tissues under artificially controlled conditions, and with the assistance of engineering and technology, whereas genetic engineering is focused on direct manipulation and modification of genes through biotechnologies (Fig. 4). The following is a frequent ethical question in tissue and cell engineering: Is it morally justified to destroy a living embryo in order to obtain cells needed to grow new ones, or for growing of tissues? Moreover, cell modification in genetic engineering represents a great danger for future generations, primarily because it is yet unknown and cannot be predicted with any certainty, what it actually entails, and what are the consequences of such an action.
Neural engineering is a bioengineering branch which applies engineering techniques in order to determine the principles of operation of human brain, and to discover new ways in which the neural system can be improved, repaired or advanced. However, this also opens new questions such as: How would certain technologies or artificial neural systems affect a human being, his/her character and dignity? Would that system turn him/her into a semi-cybernetic entity, and would it be possible to control a human being in this way, such as his/her moods and behaviour [10].

6. Prosthetics and biomaterials

There are biomedical engineering fields that focus on the development of prosthetic devices and implants, and in these fields usage of biomaterials is very common. This is complementary to tissue engineering, and represents any substance that has been engineered to interact with biological systems for a medical purpose, such as to replace, treat, augment or support living tissues, organs or functions of the body. The field of biomaterials contributes substantially to the development of innovative prostheses and implants in biomedical engineering. The development and use of prostheses and implants is a major concern in rehabilitation engineering, a field concerned with developing technological solutions for problems of people with disabilities and functionality impairments. Prostheses such as artificial hips, knees, artificial limbs, pacemakers, speech synthesizers and retinal implants are used to restore previously lost or diminished bodily function (Fig 5.). The use of prostheses and implants raises issues of human identity and dignity because it involves the addition of artificial structures and systems to human biology, or even the replacement of human tissues and organs with artificial ones. The main ethical issue in this field is the use of prostheses and implants, particularly ones that have parts performing complex functions, which, in part, makes humans into cyborgs, meaning part human, part machine. Consideration should be given to whether humans are still autonomous persons when they rely on electronic circuitry or machine part embedded within their bodies, and whether certain organs or functions should or should not be replaced by artificial systems. In addition, the possibility that prostheses and implants may be developed for human enhancement has also met with controversy [11].

Fig.4. Cell modification in genetic engineering [9]
Therefore, when constructing prostheses and implants, ethical issues should be considered as well, primarily regarding the meeting of certain conditions that need to be met in order to satisfy the requirements for ethical and responsible testing of new implants and biomaterials. One should examine the manner in which certain product is tested, and also re-examine the testing methodology, such as whether testing could be performed on human or animal bones, or by using artificial bone material. Moreover, one should also consider the ethics of clinical trials, them being subsequent to the development of the product, and preceding the launch of the product on the market [12].

Fig.5. Knee replacement [13].

7. Conclusion

Today's technology and the development of the engineering provides a variety of products and services that, not so long ago, man could simply not imagine. However, everything should be made for the benefit of the human, mankind should come first, and engineers need to be self-critical and knowing ethics very well when they are designing something. It's rewarding in itself to be a scientist and an engineer, but science should be there for the benefit of humankind, it should be imbued with spirituality and faith and should know its limits. All engineers should familiarize themselves as much as possible with their respective ethical codes as well as to analyses relevant case studies in ethical conduct. Without this knowledge, engineers may find themselves in a situation which is forcing them to compromise on some of their ethics. An engineer with a strong knowledge and background of these ethics would be able to handle issues appropriately or circumvent ethical issues entirely. With all engineers adhering to ethical guidelines established for their benefit, mankind should continue to grow and engineering should continue to bring countless new technologies and innovations into the world, without playing with the nature. Several ethical concerns and requirements need to be taken into account when social engineering research is conducted to ensure that harm does not befall those who participate in such research and it is necessary to refer to the code of ethics of engineers. Knowing and exploring ethic and bioethics is extremely important for cutting age science relates to real-world scenarios and product and procedures development. Finally, awareness of the importance of ethics and bioethics can be increased only by educating, it would be necessary severity in schools and colleges ethics and bioethics as a compulsory course.
REFERENCES


