

Ethical Responsibility in Engineering: A Fundamentation and Proposition of a Pedagogic Methodology

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Abstract — *The Encyclopaedia Britannica defines engineering as: “The professional art of applying science for the optimum conversion of natural resources for mankind.” If we accept this definition we can see that the emphasis is on scientific knowledge and knowing how to apply it. Engineering is a science, which according to Ortega [23], on the basis of scientific knowledge imposes reforms on nature to adapt it for the well being of humanity. In our opinion this means that following the maxim “knowledge is obligation”, the knowledge and power of the engineer must be matched by their sense of responsibility and because of this a consciousness of ethical responsibility is intrinsic to the development of an authentic practising professional in engineering.*

The fundamental objective of this presentation is to promote arguments in favour of the development and introduction of ethics in technical studies in universities. We will start with a short presentation of the changes in the social context that increase the risk and the responsibility of the work of engineers. We will define the concept of ethical responsibility, justify its preeminence over others such as juridical responsibility, and we will promote the vital necessity of this concept of responsibility in the field of science and technology [19]. Thirdly we will present a proposition of a pedagogic methodology in which the students internalize the knowledge and develop the skills and values necessary for the responsible practice of professional engineering [32]. Fourthly we will present the teaching experience of the subject applied ethics in the Polytechnic University of Valencia in the last years. Here we will speak about the limitations and the possibilities of its development, and we will give some provisional conclusions about its impact on the students. We will conclude focusing on the challenges ahead and work needing our urgent attention.

Index Terms — *Ethics, Professional Accountabilit, Responsibility.*

INTRODUCTION

For some decades now, the *Applied Ethics* subject is gaining importance in the curricula of the most relevant professional studies of our society.

Medicine and other health sciences were the pioneers. Although it is true that the Hippocratic oath dates back more than 25 centuries, it was in the 1960's when bioethics began to emerge with specific force. They were followed by other applied ethics such as journalistic ethics, business ethics, science and research ethics, public administration ethics and, as it could not be otherwise, engineering ethics with its diverse specialities.

This new relevance of moral questions in the professional praxis doesn't respond to a mere fashion, as some affirm, but to the upgrade of an authentic necessity that was latent in a part of our world.

In the field of engineering, some lamentable cases like the Challenger explosion, the Bophal accident, or the famous case Ford Pinto sensitized professionals and civil society about the engineer's and scientist's responsibility. The necessity of a consciousness of responsibility in accordance with our destructive potential, as pronounced already in the late 70's by the German philosopher Hans Jonas [19], became popular after some serious accidents with great public impact.

In our opinion, in this world characterized by globalization and technological development, to take ethical questions in consideration is not an option but a necessity.

THE NECESSITY OF THE ETHICAL RESPONSIBILITY

The human being is a being capable of assuming responsibility. "Responsibility means to be willing or to be able to respond to somebody for something. That is to say, we are responsible for something (action, decision, task, etc.) and to somebody or some authority" [21]. Carolina Whitbeck presents a definition with other shades: "Moral responsibilities derive either from one's interpersonal relationship to a person whose welfare is in question or from the special knowledge one possesses, such as professional knowledge that is crucial to an aspect of another's well-being" [30]. As these two definitions demonstrate,

responsibility is a very general and too formal concept that presupposes an unit behind which several different meanings and partial interpretations hide. In a first analysis we can distinguish four concepts of responsibility [20]:

- The responsibility for the consequences of our action (causal responsibility). Where a person is responsible for the results of his/her action or of the omission of his/her action (negative causal consequence). Also in the field of the causal responsibility there is to be considered a type of responsibility very frequent in engineering which is the responsibility for prevention.
- Shared responsibility (Halbbarkeitverantwortung) that refers to the responsibility that somebody has for the performance of another person (for instance the father with regard to an unable son). This type of responsibility also includes the responsibility of the boss for the performance of its subordinates; it is the so called control and management responsibility.
- The responsibility derived from the task or the role that occupies the agent is the one that refers to the special responsibility of role or of a professional qualification. Here it would be necessary to differentiate between the internal responsibility (towards the members of the organization or the profession) and the external responsibility towards the society.
- The responsibility based in the capacity is that responsibility that derives from our aptitude to do something. That is to say, if someone is qualified to understand, to plan, to act and to judge, and if he/ she possesses the knowledge and capacity of accomplishment as well as the demanded qualification.

From an analytical point of view it would be interesting to examine each of the concepts in the profession of engineering, but we should understand that the reality is complex and that concrete situations do not reflect in pure sense these concepts of responsibility but do include normally several of them.

Besides this classification - presented here only schematically for lack of space - it is suitable to make also a great difference between the moral responsibility and the legal responsibility, for the lamentable confusion that we find in many cases. The moral responsibility refers to the general values of humanity, dignity and of the quality and the improvement of the human life [20]. The essential characteristics of the moral responsibility are: universal, that is to say it does not depend on the role or on the area; unlimited and indivisible, that is to say it is applicable to any person in the same situation and can not be delegated nor distributed; it is not punishable, that is to say acting in a irresponsible form is not punishable, beyond the social shame or the conscience; and finally, it cannot be waived, it is not possible to act without responsibility in moral questions.

On the other hand, the legal responsibility derives from the legislation in force in a certain time and space (it is not universal); it is limited and divisible, is punishable and there can be areas where for lack of legality it is possible to act in a a-legal way. These essential characteristics of the legal responsibility presented here briefly show its limitation to respond to the performance in many areas of science and technology. A clear example are the advances in genetic engineering, biotechnology and information technologies.

We believe that it is fundamental to think with rigor and depth in a concept of responsibility according to our technological potential in order to advance to a safer and juster world.

JUSTIFICATION OF THE STUDIES OF ETHICS IN ENGINEERING

The British Encyclopedia defines engineering as: "the professional art of applying the science for the ideal conversion of the natural resources for the use of the humanity". If we accept this definition of the engineering profession we see that it leads us directly to ethical aspects. We see that the emphasis is on the scientific knowledges and in knowing to manipulate. This means that following the maxim "Knowing implies responsibility", the obligations of the engineer must be at the level of his knowledge and his power.

Another interesting definition of engineering is the one presented by Gómez-Senent, who affirms that: "An engineer is a professional who uses technologies – and the knowledge that he possesses of diverse technical systems: objects of all kinds and, in particular, machines, tools and instruments – to create other technical systems that satisfy certain human needs" [17]. In this definition we can also see that the central point are the human needs with all the implications that this bears. Simply assuming with rigor these definitions we can convince ourselves that the need of ethics in engineering is nothing superfluous or added, but it is in the essence of engineering profession.

If we focus now on the ethics of the engineering, we can define these as: "the study of the cases and moral decisions that face individuals and organizations in the field of the engineering; as well as the study of questions relative to moral ideals, the character, political and relations between persons and corporations involved in technological activities" [21].

As the definition affirms, the ethics of the engineering combine the analysis of values, an explanation of its meanings and of facts.

- The first and central aspect of the ethics of the engineering is the normative analysis, that is to say the identification and the legitimization of the moral standards and procedures that should guide the individual or the group. These questions refer to what we should do and to what is the right thing.
- The second analysis refers to the conceptual clarification, that is to say to explain the meaning of the principles, the concepts and the matters. For example what is bribery, what means to say the truth, how becomes definite the engineers' obligation to protect the safety and the well-being of the persons.
- The third level of analysis refers to the factual question or the one based on facts. In this third level we try to discover the values on which certain facts are based on, and simultaneously to discover the authentic facts that wrap certain situations.

Today the consequences of the human creativity in the area of the engineering have reached quotas that only a few decades before were unimaginable, and this power and development mean an enormous quantity of power and therefore of responsibility. The possible problems and dilemmas that arise from the performance of the profession must be analyzed in the light of the ethical perspective and considering the principles of human dignity.

Of course a subject of engineering ethics can neither consist in a set of procedures or concrete values that are applied mechanically to problematic situations, nor try to inculcate a certain set of beliefs. The purpose of the *engineering ethics* is to increase the skill of moral judgment and to develop the moral autonomy of the engineer. Its principal aim is to improve the skill to think critically about moral aspects in the professional area.

The incorporation of ethics in the plans of study implies, in our opinion, at least two important consequences: the first one is that it reaches wider diffusion and generates major sensibility at the same time that it qualifies the students to face ethical problems; the second but not less important one is that implicitly it shows that the society considers this subject essential in the formation of good professionals.

To our judgment, the institutionalization of a subject of engineering ethics in the study plan is as well a social demand as it is a moral intrinsic exigency to any human being who acts (and even more if, as it is the case of engineers, their actions can have such enormous impact on the life of other persons).

The fact of living in a complex, global, intercultural world and the unquestionable technological power of the contemporary societies, make necessary that professionals of engineering amplify the horizon of their technical knowledge with humanistic aspects and to complement their specialized formation with the development of skills, capabilities and values according to a global world and a modern society.

We can concrete three reasons to stimulate the development of a subject of ethics and deontology for engineers:

- In view of the enormous power of science and technology and the risks that these carry it is indispensable to develop the conscience of moral responsibility of engineers.
- There exists an urgent need to complete technical knowledge with the development of values, attitudes and knowledge that facilitate the professional excellence.
- It is necessary to develop social skills and capabilities of team work based in the respect to the proper values of civic ethics [6].

These considerations are not new, the need of a formation in ethics already appeared explicitly in Kramel's declaration on technology and moral responsibility in 1974, and they have been taken very seriously in the Anglo-Saxon countries, especially in the USA, and step by step they are gaining importance in the whole world.

In consequence with what has been said above, the general objectives that we pretend to reach with the development of a subject of ethics of the engineering are:

- To increase the knowledge about the duties and moral responsibilities of the engineers in the performance of their professional labor.
- Transmit essential ethical values for the performance of the profession.
- To develop human and social skills for team work and innovation.
- To complement the technical perspective with moral judgments to favour a responsible decision taking that attends not only to the legislation in force, but also to the exigency of universal moral principles.
- To promote the knowledge and development of professional virtues to obtain excellent engineers that contribute to the progress and the social justice.

These can be summarized in the general objective to complete the excellent technical knowledge of engineering students with the development of the capability of moral judgment and ethical values.

PROPOSAL OF A PEDAGOGIC METHODOLOGY

The methodology used in this subject is eminently practical. With this active methodology, we seek to make the students internalize values in a critical way, develop responsible attitudes and get used to think like authentic professionals. We have to bear in mind that they are students with a great analytical capacity and an enormous intellectual rigor principally orientated to the solution of concrete problems; but that they use to lack (due to the proper nature of their studies) capacity of conceptual abstraction and of flexibility of perspectives. This demands to centre on an active methodology that allows them to "apply" the concepts and perspectives to their area of professional work.

This eminently practical approach is not opposed to the theoretical ethical rigor. To our judgment, it is important that the students acquire a few - but rigorous - ethical concepts that help them to clarify the judgments on concrete situations, at the same time that it makes them see that the rigor does not limit itself to the exact sciences only.

The educational methodology that we follow is based on a series of pedagogic techniques that are inspired in the program EUROPE (an education orientated to learning) of the Technical University of Valencia [31]. Let's see it briefly:

- Magisterial lessons to give the theoretical contents of the program. The magisterial lesson is used to explain some basic ethical concepts and present their implications and limitations. In our opinion, the magisterial lesson is very important because it presents clearly and rigorously the fundamental ethical concepts without which it would be impossible to proceed to posterior analyses.
- Practical lessons in classroom, where the teacher raises problems and practical cases and offers guidance in their resolution, to guarantee the theoretical contents and to strengthen the dialogue and the reasoned participation. Some of the techniques that we use in the practical lessons in classroom are: analysis and discussion of practical cases in groups, the debate and discussion on diverse audio-visual material, and the utilization of the role-playing of problematic situations where the students get used to thinking and acting as authentic professionals, etc.
- Practical lessons in laboratory, where there are to be carried out a series of exercises, cases and works that the student has to resolve in team work, normally by means of managing computer tools. The laboratories exercises use to focus on the search of documentation on centers of professional ethics as well as on information about engineering ethics.
- Seminars of support to the work of the course or orientated to the generation of discussions and debates cause to processes of induction and deduction. In these seminars there is given an intensive use to the information and documentation found in the mass media or in the laboratories exercises. The use of practical material (newspaper articles, professional documents, etc.) fulfills the double function to involve the student with aspects of the professional reality and simultaneously to show them that ethical questions are in the agenda of the professional occupation and of the social reality.
- Work directed in the classroom. In these meetings the students are asked to work in a group on a specific topic proposed by the teacher. The students have to select and to organize the dispersed received information about a case or a proposed topic, in order to elaborate on this basis a document that resumes the central aspects of the case, an analysis of the situation and a proposal of a solution. The level of independence, of flexibility and of autoorganization that is demanded from the students is very high. It is them who decides what information is relevant, what decision they consider more suitable and why. The role of the teacher consists in giving orientation and solving punctual doubts.

THE EXPERIENCE OF TEACHING APPLIED ETHICS IN THE UPV

The teaching of the subject of " Ethics and deontology " began in 1997 in the Superior Technical School of Industrial Engineers of the Technical University of Valencia with the participation of 35 students. Since then the interest for this subject has not stopped growing. In the course 2002/2003 eight subjects have been given in five centers: ETS Industrial Engineers (Applied Ethics, Ethics and Deontology, Civic Education); ETS Agricultural Engineers (Bioethics, Ethics for Agricultural Engineers); Gandia's Superior Technical School (Ethics in work and professions); Faculty of Administration and Management (Business Ethics) and ETS Civil Engineers (Ethics for civil engineers). On the whole, in the present academic course more than 300 students have taken part in these subjects. Also the evaluation of the students of the subject is very positive.

Furthermore we should look at the receptivity of this subject in teachers of other subjects. We think that also in this point the result is optimistic. In the last two years there have been given three courses of educational ethics to teachers in which participated more than 60 teachers; and a course in education in ethical values in scientific technical studies with a participation of more than 20 teachers. Some of these teachers, together with others, have created the Group of Innovation in Education in Values in Scientific Technical Studies that for more than one year is working on the development of the proper moral values of civic ethics in their respective subjects (statistics, electronics, drawing, engineering projects, hydraulics, etc.).

CONCLUSIONS

Our idea and experience of the development of the education of engineering ethics can be summarized in three points:

- It is a necessary subject. More and more, the engineers face problems that use to have important effects on the life of other persons; what is more, the increasing asymmetry of knowledge between the professional and his client brings with it a major need of confidence; and finally the risk of loss of professional autonomy is increasingly worrying. These are only some of the most important aspects that claim a complementation of the technical with the moral knowledge. We should not forget that to act responsible not only requires technical but also moral formation.
- It has to be an integrative approach. The development of a subject of this nature needs to develop an integrative approach that shows clearly that ethical questions are implicit to the professional performance and that they are not an " external extra to improve the professional image ". Simultaneously the integrative approach should suppose implication and a commitment with the specific problems of the profession of engineering.
- It has to follow a practical methodology. To obtain the effect that we aim at, requires the use of a practical methodology in which the student is the actor who is discovering the keys of ethically knowledge. To transmit ethical knowledge it is necessary that the student stops being the passive subject receiving knowledge and is converted into the active subject that discovers and shapes his moral conscience of responsibility.

The formation of the most responsible professionals and with a major ethical conscience it is nothing of second order, but it is a necessary condition for the survival of the world (and for a juster world) and an exigency of justice that the society cannot ignore any more. The universities and center of superior education should take this seriously and do everything possible to form authentic persons and not simply good technical professionals. More than fifty years ago, Einstein wrote in a brief article in The New York Times: " It is not enough to teach a man a specialty. Through it he may become a kind of useful machine but not a harmoniously developed personality. It is essential that the student acquire an understanding of and a lively feeling for values. He must acquire a vivid sense of the beautiful and of the morally good. Otherwise he, with his specialized knowledge, more closely resembles a well trained dog than a harmoniously developed person." [11]. Humbly, we believe that, today more than ever, this affirmation continues being valid.

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