Necessary Knowledge for Social Responsibility of Scientists and Engineers

Henk Zandvoort
Delft University of Technology, Faculty of TPM, Netherlands
h.zandvoort@tbm.tudelft.nl

***Abstract* – There exists well-founded knowledge that is necessary for social responsibility of scientists and engineers. This knowledge should be transferred in the science and engineering curricula as otherwise it will remain unknown to (future) scientists and engineers. Examples of such necessary knowledge are described about two selected subjects, namely: (1) the factual ("positive") and normative properties of procedures for collective (political) decision-making; and (2) the foundations and functioning of the legal system. Although valuable sources for the knowledge referred to under (1) do exist, this knowledge is currently not included in the mainstream science and engineering curricula. An analysis of two textbooks on engineering ethics reveals that these textbooks are inadequate as sources of knowledge on the two subjects identified in this paper.**

It is argued that the effective transfer of the "necessary knowledge for social responsibility" identified in this paper requires more study time than is currently available for such subjects in the "hard" science and engineering curricula. It is concluded that the question, how much study time should be devoted to "non-technical" subjects such as the ones identified in this paper, has not been satisfactorily settled and should be opened for discussion.

Index Terms – Ethical and social responsibility, Foundation and functioning of law, Procedures for collective decision-making, Science and engineering curricula.

I. Introduction

For the effects of their work on society, scientists and engineers are highly dependent on the proper functioning of the legal and political systems and institutions. To a high degree, laws and political decisions determine how their work will be used and to what effect: whether unintended side effects will be controlled, whether risks will be contained, and whether costs and benefits will be distributed fairly. In short, it is laws and political decisions that determine whether the output of scientists and engineers will be beneficial and not detrimental to society. This holds both for engineers and for scientists, including the large majority of scientists working in fundamental science, as most of that fundamental science is being performed and/or financed because of the expectation of practically applicable results. In addition, the vast majority of engineers and scientists perform their work as employees of (either private or public) hierarchical organisations. These organisations both enable and constrain the work of engineers and scientists in essential ways, and have a pervasive impact upon both *what* engineers and scientists do, and *how* they do it. These organisations are created, and their functioning is determined, by the legal system.

It cannot be taken for granted that the legal and political systems are up to their tasks. As I have explained elsewhere [1], important flaws can be identified in the existing laws and in the existing procedures for political decision making, if considered from the perspective of an engineer or a scientist who wants to perform his/her work in an ethical or socially responsible way, and/or who wants to contribute through his/her work in a positive way to society.

However, laws and procedures for collective decision-making are man made, and can be *changed* by humans. Scientists and engineers could contribute positively to democratically effectuated change of these social institutions. A necessary condition for this is that they should be informed about relevant and well-founded knowledge that exists about these institutions and their functioning. Without that knowledge, they are not in the position to formulate sound opinions on the actual functioning of these institutions and on options and proposals for change. Here, "sound" is used in the sense of: consistent with existing relevant and well-founded knowledge. Such knowledge is termed here "necessary knowledge for social responsibility".

In this paper, the claim will be defended that there exists knowledge that is both necessary for social responsibility and largely unknown to or at least poorly understood by (future) engineers, and that should be transferred to future scientists and engineers through the curricula, as otherwise that knowledge will remain unknown to them. In substantiation of this claim, examples of such knowledge are presented, dealing with the following two subjects:

1. The procedures for collective decision-making;
2. The foundation and functioning of law.

The second subject will be narrowed down to a particular, though important aspect, namely the foundation of legal liability.

These two subjects do not exhaust the list of subjects that should be considered from the perspective of necessary knowledge for social responsibility. Other subjects that belong in this list include the following:

- The functioning of hierarchical organisations and of people who work in such organisations. (Hierarchical organisations in many respects play a dominant role in present day society; the great majority of engineers, like many other higher educated people, are employees of

and hence are constrained in their work by such organisations.)

- The theory of decision-making under uncertainty.[1] (Mastering of this theory can be said to be necessary for a proper understanding of the ethical aspects of technological risks.)
- Game theory and the theory and phenomenology of negotiation.[2]

All the knowledge that is delineated above is actually relevant for all citizens, and more importantly so for all higher educated persons who are likely to occupy influential positions in society and to do work which has a high impact upon others. In this paper, however, the attention will be restricted to the topics (1) and (2) indicated above and to the science and engineering curricula.

II. Overview

In Section 3, fields of study are identified that deal with the subjects (1) and (2) identified above. Two examples of "necessary knowledge for social responsibility" about these subjects are provided. Section 4 discusses the availability of textbooks on the two subjects. It is concluded that an excellent textbook on public choice exists, which is however not included in most science and engineering education curricula, especially not in the "hard" science and engineering disciplines. Section 5 provides an analysis of how two existing textbooks on engineering ethics deal with the two selected subjects, in order to see whether a course on engineering ethics based on one of these or a similar textbook could at least partially make good for the absence of courses on the subjects identified in this paper. The conclusion will be a negative one. In Section 6 the author's teaching experiences will be invoked in order to conclude that the effective transfer of "necessary knowledge for social responsibility" on the subjects identified in this paper require more time in the science and engineering curricula than is currently available for "non-technical" subjects. In Section 7 the conclusions obtained in the paper are recapitulated.

III. Examples of Necessary Knowledge for Social Responsibility: Procedures for Collective Decision Making and Legal Systems

In this Section, two important insights will be presented regarding the two selected subjects. These insights are both very well-founded and very relevant for scientists and engineers who desire to take socially responsible decisions, and yet are generally unknown or at least badly understood. These insights relate to the question whether collective decisions should be taken with unanimity or whether a majority suffices (3.1), and to the question what should be the standard of legal liability for activities (such as scientific and technological activities) that may affect others and for which those who are potentially affected have not given their informed consent (3.2). The insights presented below render their well founded nature from the fact that they have the form of "if… then…" statements, specifying deductive relations between the statements that occur at the places indicated by the dots. For that reason, the knowledge expressed in these statements may be termed "mathematical". In addition to such "mathematical" knowledge, the fields of study that will be mentioned below have also produced sound empirical knowledge about relevant factual "positive" phenomena.

The field of study called public choice has rendered important knowledge regarding both the factual ("positive") and normative (ethical) properties of different procedures for collective decision-making. The first example below stems from this field. There is not one single dominant field of study devoted to the critical study of the legal system, including its ethical foundations and including the critical assessment of how well the actual legal systems perform their intended functions. Instead, this subject, or aspects of it, is addressed by scholars working from different academic perspectives including law, philosophy, and economics.[3]

I. Unanimity decision-making and majority decision-making[4]

Many people equate democracy with majority decision-making. This inconsiderate and categorical identification is impossible for anyone who has taken cognizance of relevant results of the science of public choice. These results disclose severe negative properties of majority decision-making, both considered from a practical perspective and from a normative perspective. As for the normative flaws, majority decision-making, unlike consensus decision making, allows that a majority dictates and exploits minorities, and does not guarantee social progress under any non-arbitrary definition of "social progress".

Unanimity rule is the only decision rule certain to lead to social progress in the sense of Pareto improvement. A Pareto improvement is a change that makes at least some one better off and no one worse off. Other voting rules including majority rule lack a similarly sound and non-subjective foundation. As a consequence, the belief that majority rule leads to positive results, or to progress, is actually lacking a sound foundation. The often heard statement that democracy, in the sense of majority decision making, is the best possible way of collective decision making is likewise lacking any foundation.

[1] There exist several excellent textbooks on this subject. Examples are [2] (advanced level) and [3] (introductory level).

[2] Game theory is sometimes considered as a part of the theory of collective decision-making. For instance, [4] includes relevant contents from game theory. Also [5] has a good chapter on game theory. Negotiation can be considered as a special type of collective decision-making, but is not usually included in accounts on collective decision-making. An excellent book on negotiation that includes discussions of ethical aspects as well is [6].

[3] Public choice scholars have paid little attention to the contents of or principles underlying laws, and their discussions and insights would benefit from integration with insights pertaining to this subject. For instance, public choice scholars have not satisfactorily answered the question which (legal or ethical) principles should govern when a (binding) collective decision about such principles is lacking.

[4] Another important theme in public choice, next to the one presented here, is whether collective decision procedures should take qualitative individual preferences as inputs (as in most existing voting procedures for political offices) or that such procedures should operate on quantitative information about individual preferences. A procedure that works on quantitative input is Social Cost Benefit Analysis.

II. Standard of legal liability in the absence of informed consent

As was shown in [7], two ethical principles can be formulated that together are both necessary and sufficient for peaceful coexistence. These principles are the right of everyone to be safeguarded from the consequences of another person's actions (also called the no harm principle) and the reciprocity principle.

The right to be safeguarded expresses the right of everyone not to be harmed by the activities of others. This principle contains the equal right principle, but is not equivalent to that. As harm has always subjective elements, it can be ascertained in only two ways that an activity will not harm others. Either, there are no (actual or possible) consequences for others. Or there are (actual or possible) consequences for others, but these others have given their informed consent to the activity. Hence, the right to be safeguarded implies a principle of informed consent: For all activities, all those who may experience the negative effects including the risks of the activities must have given their informed consent to the activities and the conditions under which the activities are performed.

The reciprocity principle says that he/she who violates a right of another one may be reacted to in a reciprocal way. That means that somebody who infringes a certain right of another will himself/herself lose that same right insofar as that is necessary (and no more than that) in order to correct the original violation or to compensate for it and in order to, if necessary, prevent further infringement. Hence, someone who does not respect another person's right to be safeguarded and who thereby causes another person harm, loses his/her own right to be safeguarded, in the sense that he/she may be forced, without conditions, to repair or fully compensate the harm. It thus follows that the liability for harm from activities that have not been consented to by those who experience the harm should be strict, that is full (unlimited, no caps) and not subject to conditions such as "fault" (unconditional).

Taking into consideration that laws are actually introduced or altered via (national) majority decision-making as opposed to consensus decision making, it follows that, in order to respect ethical principles which are necessary for peaceful coexistence, the standard of liability in the legal systems should be strict, i.e. unconditional and unlimited liability. The actual legal systems deviate from this standard in important ways. In addition to being required for peaceful coexistence, strict liability is an indispensable instrument for effective management and control of risks and other side effects of technology.

IV. AVAILABILITY OF KNOWLEDGE ABOUT PROCEDURES OF COLLECTIVE DECISION MAKING AND LEGAL SYSTEMS

I. Collective decision making

The main results of the field of public choice are available through textbooks, notably the highly acclaimed book *Public Choice III* by D.C. Mueller [4]. This advanced textbook is an invaluable source of "necessary knowledge for social responsibility of scientists and engineers" on the subject of collective decision-making. With its length of about 750 pages and its use of mathematical language in the style of economics, the study of this book requires a full-length course. There exist a few books at introductory level that are much shorter and do not use mathematical language, but the author does not know of the existence of introductory books that are really satisfactory. [5]

In academic study programmes on economics, the study time required for a book like [4] is readily available. In the mainstream curricula on science and engineering (the so called "hard" disciplines such as physics, chemistry, electronics, mechanical, civil, etc.) this is very different, however. In these programmes, the amount of curriculum time available for "non-technical" (i.e. non-science or non-engineering) subjects is usually 10% of the total curriculum at most. Much of this 10% is devoted to skills like oral and written presentation and factual ("positive") knowledge on specific subjects like business economics and business law. This means that only a fraction of this 10 % is actually available for transferring "necessary knowledge for social responsibility" on the subjects identified in this paper. That space is insufficient to include, for instance, a course on public choice based on [4]. Even if satisfactory shorter accounts were available, it would in most science and engineering curricula remain impossible to find the required study time within the time that presently is allotted to "non-technical" subjects.

II. Critical analysis of legal systems

There is a pressing need for good textbooks on this subject. The present author is not aware that such books currently exist.[6] Even when good textbooks were available, the practical problem of giving them a place in the science and engineering curricula would remain, as was discussed above for the subject of pubic choice.

V. TEXTBOOKS ON ENGINEERING ETHICS

In some engineering curricula a required course on engineering ethics is included. It is possible that such courses will be included more often in the future, for instance in response to developments in the criteria set by accreditation agencies. In view of the intended objectives of such courses, one might expect that due attention is given to transferring necessary knowledge for social responsibility on the topics indicated in this paper. In order to test this expectation, I have scrutinised two widely used textbooks on engineering ethics from the point of view of how they deal with the two subjects identified in this paper. The analysis, to be presented below, is discomforting, as it shows that these two textbooks are very much inadequate from the perspective of transferring the "necessary knowledge for social responsibility" identified in the preceding section. I should

[5] An introductory text on public choice is [5]. There are good chapters on the empirical ("positive") properties and effects of different procedures for collective decision-making that are actually in use. It has also a good chapter on game theory. However, the account of the normative/logical properties of decision procedures is seriously flawed.

[6] A book that should be brought up for consideration is [8], but this book is currently available only in Dutch.

stress that the following is not a full analysis of the contents of these books. I merely want to show that the textbooks are inadequate from the perspective considered in the present paper. In order to do that, I have focused on the topics or chapters in these books that are the most relevant from the present perspective. These topics do not exhaust the contents of these books, although they do belong to their core contents. In addition, these two books are typical examples of what to expect of current textbooks on (science and) engineering ethics.

I. Martin and Schinzinger: Ethics in Engineering [9]

An important starting assumption and structuring principle of this book is that engineering is a form of social experimentation that requires the informed consent of all who are subjected to its effects:

> "Viewing engineering as an experiment on a societal scale places the focus where it should be: on the human beings affected by technology; for the experiment is performed on persons, not on inanimate objects. In this respect, albeit on a much larger scale, engineering closely parallels medical testing of new drugs and techniques on human subjects. […] While current medical practice has increasingly tended to accept as fundamental the subject's moral and legal rights to give informed consent before participating in an experiment, contemporary engineering practice is only beginning to recognize those rights. We believe that the problem of informed consent, which is so vital to the concept of a properly conducted experiment involving human subjects, should be the keystone in the interaction between engineers and the public. […] Informed consent is understood as including two main elements: knowledge and voluntariness. First, subjects should be given not only the information they request, but all the information needed to make a reasonable decision. Second, subjects must enter into the experiment without being subjected to force, fraud, or deception. Respect for the fundamental rights of dissenting minorities and compensation for harmful effects are taken for granted here." ([9], p 84-5)

In agreement with this, the authors provide in another chapter the following definition of acceptable risk:

> "A risk is the potential that something unwanted and harmful may occur. A thing is safe for persons to the extent that they judge (or would judge) its risks to be acceptable in the light of full information about the risks and in light of their settled value principles." ([9], p 181)

Discussion. In view of the starting point that engineering is a form of social experimentation requiring the informed consent of all who are subjected to its effects, one would expect ample attention to procedures of collective decision-making. At the least, one would expect a discussion of unanimity rule in collective decision-making. That discussion is completely lacking, however. This is inadequate from the perspective of transferring necessary knowledge for social responsibility. It appears that the authors were ignorant of the field of public choice. This is very regrettable, as this book could have benefited very much from the analyses and results obtained in that field.

The book offers discussions of responsibility and accountability, as well as a rather brief and unsystematic discussion of legal liability. Both topics remain disconnected from each other, however. In view of the discussion under point II in Section III above, also this is inadequate from the perspective of transferring necessary knowledge for social responsibility.

II. Harris, Pritchard and Rabins: Engineering ethics: concepts and cases [10]

In view of our goal, it is suitable to focus our attention on chapter 8 entitled "Risk, safety and liability in engineering". This chapter introduces and discusses a Principle of Acceptable Risk (in the following: PAR). The principle holds that, in decisions regarding public risks created by technology, a balancing of different ethical considerations must be made, namely the Respect for Persons (RP) consideration and the utilitarian consideration:

> "On the one hand, we must protect people from harm, especially with respect to substances that are ingested into their bodies or that pose a clear threat to life. On the other hand, this protection must be balanced against the need to preserve technologies that are irreplaceable and confer great benefits. Thus, RP morality requires that we should not subject people to dangers without their informed consent, and that harm should not be imposed unjustly. Conversely, we should be aware of the difficulties of obtaining free and informed consent in some circumstances. In the light of these considerations, we can perhaps construct a principle of acceptable risk that may provide some guidance in determining when risk is within the bounds of moral permissibility:
>
> *[PAR] People should be protected from the harmful effects of technology, especially when the harms are not consented to or when they are unjustly distributed, except that this protection must sometimes be balanced against (a) the need to preserve great and irreplaceable benefits and (b) the limitations on our ability to obtain informed consent."*
> ([10], p 234)

The authors continue that the principle does not offer an algorithm that can be applied mechanically to situations involving risk. Rather, "Its use involves many conceptual and application problems, each of which must be considered on its own merits." ([10], p 243) Four of these are the need to determine: what it means to protect people from harm; what constitutes a harm; what constitutes a great and irreplaceable benefit in the context of a particular situation; and how the criterion of unjust distribution of harm should be applied. Another issue to be resolved consists of "the conceptual and application problems that arise in determining informed consent and the limitations in obtaining informed consent in many situations" ([10], p 244).

Discussion. By presenting the Principle of Acceptable Risk that should govern decision making about activities that generate public risks, the authors clearly deal with the first subject for discussion in this paper, collective decision making. Unfortunately, as will be discussed below, the treatment of this subject is open to severe criticism.

The PAR asserts that in order to take decisions about (activities that generate) public risks, different ethical considerations must be balanced. The background of this balancing is the idea that there exist different ethical principles, more specifically Kantian "Respect for Persons" principles and utilitarian principles focused at maximising net social welfare. If applied to decision making about activities that create risks for others, these principles may yield contradictory results. Hence, person A who endorses ethical theory X might consider a decision based on theory Y endorsed by person B unacceptable, whereas conversely B who accepts Y might consider a decision based on theory X endorsed by A unacceptable. It remains in the dark why a balancing between the principles of such conflicting theories would lead to results that are deemed acceptable by both A and B. The result of the balancing might as well be unacceptable to none of them, as this result might violate both ethical theories. It ca be concluded that the PAR lacks any foundation. Perhaps the authors's idea is that A and B could both approve of the PAR by way of a compromise, but this is not made explicit, nor is it explained why A and B *should* compromise. In fact, the authors do not provide a foundation for the PAR, i.e. they do not show why everyone should accept the principle and its consequences.

Apart from lacking a foundation, the PAR is also totally inapplicable because of the indeterminate nature of the balancing. The authors display this indeterminate character of the PAR while presenting the six issues that need to be settled in order to apply the PAR, five of which have been mentioned above. Thus, any application of the PAR requires decisions on issues like: whether something constitutes a harm for someone; whether something constitutes a great and irreplaceable benefit; whether the distribution of a harm is just; and when ("sometimes") and how the protection of individual rights must be balanced against other things. All these issues remain essentially in the dark. The authors do not show, and do not even attempt to show, how such decisions can be something else than subjective or arbitrary, and hence they fail to give sound reasons why those decisions should be accepted by dissenters.

In addition, but related to this, the authors do not specify who should apply the PAR, and hence who should make the judgements required to decide the host of interpretation and application problems mentioned above. Should such decisions be taken by individual engineers? Or is it organisations such as private companies (or managers representing them) or government agencies (or officials representing the agencies)? Or should the decisions be taken by political bodies such as parliaments? If so, should they decide with majority rule or with consensus? All these questions remain hidden under the frequent use of the completely indeterminate phrase "we", and hence not merely remain unresolved, but even unnoticed.

Like the previously discussed book, the present one could benefit enormously from taking notice of sound knowledge about collective decision-making, as collected in for instance [4]. As it stands, the book completely ignores that knowledge, even though it is extremely relevant for the problems that are addressed, but by no means resolved, by introducing the PAR. In addition, the topic of liability receives in this book a very immature, fragmented, and inadequate treatment, consisting essentially of a few isolated and unsubstantiated statements on the topic.

It is concluded that the discussion of social decision-making about technological risks offered in this book is vulnerable to severe criticism. The book ignores and completely fails to transfer existing relevant knowledge about collective decision-making, and must be considered very inadequate from the perspective of preparing engineers for social responsibility.

VI. Author's Teaching Experience

In this section I present my experience with teaching the subjects identified in this paper to students of different MSc programmes in engineering at Delft University of Technology. I focus on two courses in particular, a course on "Ethics and engineering" in the Faculty of Applied Sciences[7] and a course on "Ethics in design and management of technology" for the MSc programme "Systems Engineering, Policy Analysis and Management" of the Faculty of Technology, Policy and Management.

With 6 ects credit points the "Ethics and Engineering" course for the Faculty of Applied Sciences is by normal standards in the "hard' engineering disciplines a substantial non-technical course. Yet the space thus available remains limited if compared to the body of existing "necessary knowledge for social responsibility" that should actually be transferred in view of the objective of the course, which is, basically, to prepare the students for social responsibility. In the course, a couple of lecture hours supported by lecture notes and reader texts are devoted to the topics mentioned in section III. This type of teaching effort is deemed to have limited effect, because it is not embedded in a context of courses on related topics, and because there is virtually no space for details and examples. It would be more effective to include in the curriculum a whole course on e.g. Mueller's book [4]. However, in the "hard" science and engineering curricula the space for this is lacking.

Another part of my teaching experience relates to a course on "Ethics in design and management of technology" for the MSc programme Systems Engineering, Policy Analysis and Management. About half of this programme consists of courses in "hard" engineering and technology topics, the other half deals with topics relating to systems engineering and policy analysis. This provides in principle sufficient time for a course in which important parts of the knowledge contained in a book like [4] can be transferred. Experience has shown that this material does not pose specific difficulties to these students. It should be remarked here, that in comprehending this material, these students probably benefit from their background in topics such as

[7] This course has been described in [11].

economics (including game theory and decision analysis), private and public law, and organisations and management. Of course, the students in the "hard" science and engineering disciplines are usually lacking this background.

VII. Conclusions

It was argued that there exists necessary knowledge for social responsibility of engineers that is unknown to or at least poorly understood by (future) engineers. I have stated examples of such knowledge on two subjects in particular: (1) The factual ("positive") and normative properties of procedures for collective (political) decision-making; (2) The foundations and functioning of the legal system. I have argued that the existing well-founded knowledge about these and other subjects should be transferred to future scientists and engineers through the curricula, as this knowledge is necessary for socially responsible decision making and acting, and as this knowledge will otherwise remain unknown. The knowledge identified in this paper is a prerequisite for sound critical assessment of the actual and possible role of law as regards the ethical and social aspects of technology and engineering, and for sound critical assessment of the prevailing systems and procedures of collective decision making, including an assessment of possibilities for improvement. Without that knowledge, science and engineers will be unable to formulate sound opinions on these issues, both as civilians with (passive and active) political rights and duties and as future engineers who are expected by the public to exercise their professional functions in (ethically, socially) responsible ways. Here, opinions are called "sound" if they are not inconsistent with existing relevant and sound knowledge.

For the first subject identified in this paper, collective decision-making, an excellent textbook [4] exists. For the second subject no similar book currently exists. I have argued that, in order to effectively transfer necessary knowledge for social responsibility about collective decision-making, [4] should actually be included in all engineering curricula. This is currently not the case in the "hard" science and engineering curricula, neither is the limited space that is allotted in these curricula to "non-technical" subjects sufficient for their inclusion.

In the "hard" engineering curricula a course on engineering ethics is sometimes included. In principle, such a course might partially make good for the absence of courses dedicated to the subjects identified in this paper. However, an analysis of two widely used textbooks reveals that these books, while being typical in their kind, are inadequate in this respect.

It cannot be assumed that the current allotment of curriculum time to the subjects identified in this paper are the result of a conscious weighing of competing demands that are imposed on the science and engineering curricula. Usually, those who decide on the contents of these curricula have themselves been educated through the same curricula. Hence they may be as ignorant about the existence of the knowledge identified in this paper as are the current students to whom this knowledge should be taught. Hence, on the basis of the conclusions obtained in this paper, a discussion should be opened on the question, how much time in the science and engineering curricula should be allotted to the topics identified in this paper.

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