Chapter 2
A Philosophical Analysis of the Nature of Engineering

2.1 Introduction

Some philosophical analysis of the nature of engineering can be of great benefit in identifying the ethical opportunities and challenges that it offers. This chapter will explore the overall nature of engineering using concepts provided by the work of two leading contemporary philosophers. First, the structure of engineering will be elucidated by considering it as a *practice*, of the type first proposed by Alasdair MacIntyre. Secondly, Amartya Sen's concept of *capabilities* will be used to describe the role that engineering can have in promoting both the *wellbeing* and the *agency* of others, and further to propose an *opportunity of professional capabilities* that can guide the development of the ethical aspects of the practice of engineering. Finally, the work of Sidney Loeb, a pioneer of an innovative type of engineering, will be described to provide a first illustration of how the analysis developed may be applied.

2.2 The Practice of Engineering

MacIntyre uses the term *practice* to describe a certain type of 'coherent and complex form of socially established cooperative human activity'. He gives a very specific definition of what he means by a practice:

> …any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realised in the course of trying to achieve those standards of excellence which are appropriate to, and partially derivative of, that form of activity, with the result that human powers to achieve excellence and human conceptions of the ends and goods involved are systematically extended [1].

Among his examples of practices are: games such as chess and football; artistic endeavours such as portrait painting and music; intellectual enquiries such as the sciences and history; and activities such as farming, commercial fishing and architecture [2]. Consideration of this diverse list has led Miller to propose a very

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useful distinction between ‘self-contained’ practices and ‘purposive’ practices [3]. Games are the clearest examples of self-contained practices, for here it is the activity of the game itself that is of paramount importance. In contrast, purposive practices have arisen to serve social ends beyond themselves. Thus, the social ends of the purposive practices of farming and commercial fishing are the production of food, and the social end of architecture may be considered to be the creation of functional and aesthetically pleasing buildings.

Neither MacIntyre nor Miller gives attention to engineering, but considering engineering as a practice can be very helpful in developing an ethical analysis of its activities [4]. It is clear that in Miller’s terms engineering is a purposive practice. An account of the nature of engineering can hence be developed by considering the key features of a purposive practice. Following MacIntyre, these may be considered to be: (i) the end or goal; (ii) internal goods; (iii) external goods; (iv) virtues or principles; (v) institutions and (vi) systematic extension. Each of these features will now be given some preliminary consideration.

2.2.1 End or Goal

It is difficult to devise a succinct statement of the goal of an activity as diverse as engineering.[1] Any brief statement will require further elucidation. It has been noted in Chap. 1 that the UK Royal Academy of Engineering describes what in Miller’s terms are the purposive social ends of engineering as being ‘to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources’ [5]. This has the benefit of being an ambitious statement, as is appropriate for the expression of an overall goal. However, it could benefit from further development and elucidation.

Hence, as a working definition, it is proposed to describe the goal of engineering as being *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. Here the expression ‘flourishing’ is intended to convey a richer contribution to human life than welfare, health and safety. As will be made clearer later, flourishing includes not only wellbeing but also the agency of persons in communities. This is particularly important for an enabling activity such as engineering. The expression ‘persons in communities’ provides a starting point for the elucidation of ‘all’. First, it recognises that though engineering is concerned with promoting the wellbeing of communities, it is also concerned with promoting the wellbeing of each individual person in those communities. Hence, great care and discernment will be needed if engineering activities lead to potential conflict between the wellbeing of communities and the wellbeing of some of the persons of which they are comprised. Second, the term ‘communities’ is taken to include cooperative social groupings of all sizes,

[1] Engineers use the term ‘goal’ to describe what a philosopher might term an ‘end’.

including cooperation beyond the boundaries of nation states or close political alliances, at which societies tend to draw their limits. Third, as communities have a history and a future that extends well beyond the lifetime of any individual person, this definition implies a commitment to both social and environmental sustainability. Furthermore, the expression 'through contribution to material wellbeing' provides a starting point for describing the specific means by which engineering seeks to promote human flourishing. These involve the use of science and mathematics combined with reason, imagination, judgement and experience.[2] Consideration of the internal and external goods of engineering will make these means clearer.

2.2.2 Internal Goods

The purposive practice of engineering seeks to benefit persons and the communities in which they live. However, it is not an ascetic activity. Indeed, there are certain goods which not only require knowledge of the practice for specification but which are also best, or in some cases only, recognised by and available to those participating in the practice. These goods characteristically benefit all participants in the practice, and in some cases also all those affected by the practice. MacIntyre terms these internal goods.

Many of the internal goods of engineering are particularly associated with technical excellence. Some of these are subjective. Engineering characteristically involves the imaginative and practical use of science and mathematics. Thus, the practising engineer directly experiences certain goods, such as the satisfaction of finding an elegant mathematical formulation of an engineering problem or the intellectual reward arising from the development of an ingenious practical solution in the design of an innovative piece of equipment. Such excellence becomes objective when it is recognised by other practitioners. There may often be broad consensus among engineers as to what constitutes such engineering excellence, though expectations and standards will develop with time.

The goal of the promotion of the flourishing of persons in communities through contribution to material wellbeing is associated with certain characteristic internal goods that are broader in scope.[3] Thus, all engineers give great priority to safety: the safe operation of products and processes is of paramount importance in engineering practice. However, as no human activity is entirely free of risk, the assessment of safety and balancing of benefits and risks is challenging. Quantification of safety and risks is very important, but qualitative public perceptions also need to be taken into account. Cost-effectiveness is an another important internal

[2] Engineering also facilitates science in many ways, the largest scale example being the Large Hadron Collider (LHC) at the European Organisation for Nuclear Research (CERN).

[3] I thank Jon A. Schmidt for emphasising this point to me.

good of which all engineers are continually aware. This can be a significant feature of safety assessments, but has a broader significance in bringing the benefits of engineering to as many persons and communities as possible. Furthermore, as already noted, social and environmental sustainability are such central concerns of engineering that they feature in almost all engineering activities and may be considered internal goods in this wider sense.[4] In Chap. 7 a case will be made for considering the promotion of human rights as an internal good of engineering. In Chap. 8 it will be proposed that the pursuit of peace should be regarded as such an internal good.

Finally, it is important to note what is for many engineers the greatest subjective internal good of all: the satisfaction of contributing to the flourishing of persons in communities. This provides a strong intrinsic motivation for the work of engineers. Indeed, intrinsic motivations of this type can be stronger than tangible external rewards for they change the character of the activity [6]. It is in such a way that an ethical approach to engineering can promote the quest for technical excellence. This may be particularly apparent when the engineer and beneficiaries are in close proximity.

2.2.3 External Goods

MacIntyre's characteristic examples of external goods are prestige, power and wealth. It is distinctive of such goods that they are the property or possession of an individual or group, and that they are typically achieved in competition, resulting in losers as well as winners. Goods such as these are often contingently attached to practices and could, in principle, be achieved in other ways. However, purposive practices also give rise to external goods that are specific to their activities, such as fish in the case of commercial fishing and buildings in the case of architecture.

The practice of engineering gives rise to considerable economic benefits for the communities in which its activities take place. Countries with innovative and productive engineering sectors are noted for their economic strength and stability. Also, as engineering is not as ascetic activity, engineers themselves derive significant financial rewards for their work. Indeed, this is an important extrinsic motivation for the work of engineers. Engineers may attain a certain prestige on account of their profession, and a few may even become famous. However, power is not usually considered to be an external good of engineering, at least in a political sense.[5]

[4] For this reason, the goal of engineering should be understood as 'the promotion of the flourishing of persons in communities *in an environment* through contribution to material wellbeing'. However, this is left implicit as persons and communities are always in an environment. The importance of several types of environment will feature in later chapters, including work environments, social environments, built or engineered environments and natural environments.

[5] This view is challenged in Chap. 7.

Rather, the most obvious characteristic external goods of engineering are technological artefacts, the many products and processes on which modern society depends. As noted in Chap. 1, among the most beneficial are clean water production and sanitation, energy generation, large-scale pharmaceutical manufacture, hygienic food processing, transport infrastructure, mechanical devices, medical diagnostic equipment, instrumentation, computing and telecommunications.

It will be noted that many of these technological artefacts not only contribute to human wellbeing (such as welfare, health and safety) but also enable others to choose the type of life they wish to live. Hence, it can be appropriate to consider further the external benefits of engineering in terms of Sen's concept of *capabilities*, the various things that a person manages to do or be in leading a life [7, 8]. Such capabilities he describes in terms of both *wellbeing* and *agency*, the latter being the possibility to advance whatever goals and values a person has reason to advance. Wellbeing is particularly useful in assessing issues of distributive justice. Agency gives attention to the person as a doer. The specific inclusion of agency allows for a much richer description of benefits than consideration of wellbeing alone. For example, a person may have reasons for pursuing goals other than personal wellbeing or individual self-interest, including promoting the wellbeing of others and respect for their agency.

Sen further characterises wellbeing and agency in terms of *achievement* and *freedom*. Freedom refers to a person's options and opportunities, and may have a plurality of expression, including basic aspects such as freedom from hunger and higher level aspects such as developing self-respect or creative fulfilment. He notes that such freedom has not only instrumental but also intrinsic value, and may be directed to the benefit of others.

Taken together, this analysis yields four concepts of benefit to a person: (i) *wellbeing achievement*; (ii) *agency achievement*; (iii) *wellbeing freedom*; (iv) *agency freedom* [9]. This fourfold classification of advantages seems particularly useful for thinking about the external goods of the essentially *enabling* activity of engineering. Furthermore, the approach is general enough to allow for a great range of specific circumstances. For example, persons in poorer communities may particularly benefit from provision of necessary basic goods, such as clean water and sanitation. These may already exist in wealthier communities, where wellbeing and agency may be further advanced by additional consideration of how further benefits, such as cultural goods, are provided. In all circumstances, wellbeing and agency are important aspects of human flourishing.

It is worth emphasising a key effect of considering capabilities as external goods of engineering: attention is moved from engineering as the provider of physical artefacts to the effects of engineering on the lives which people are able to lead. That is, consideration of capabilities promotes an emphasis on the ethical nature of the practice of engineering. As will become clear in later chapters, the consequent consideration of both wellbeing and agency changes priorities in engineering. An emphasis on engineering as a provider of physical artefacts leads to engineers posing questions of the form 'what kind of technology can best meets the needs of a person or community?'. In other words, consideration of what can be *done for* the person or community, placing the person or community in a passive role. A consideration of capabilities additionally asks 'what can the person or community *do*?', acknowledging that the person or community can be active contributors to their flourishing. Furthermore, although engineering can have a great influence on such flourishing, engineers need to maintain modesty about their contribution. As one of the pioneers of ethical approaches to engineering in the UK, Meredith Thring, has eloquently observed, each engineer must realise that '*the subjective qualities of human life, such as self fulfilment, happiness, inner freedom, and love, have much more real long-term importance to the people affected by his [or her] engineering than does the possession of goods and status symbols beyond those necessary for a full life*' [10].

It should be borne in mind that there is not always a sharp distinction between internal goods and external goods. Thus, safety, cost-effectiveness and social and environmental sustainability have here been considered internal goods of the practice of engineering. However, their specific instantiations are clearly of benefit to others and hence comprise external goods of the practice. As a contrary example, some features of external goods, such as ingenious features of technological artefacts, may only really be appreciated by engineering practitioners even though the artefacts as a whole are of great benefit to others.

2.2.4 Virtues or Principles

According to MacIntyre, a virtue is 'an acquired human quality the possession and exercise of which tends to enable us to achieve those goods which are internal to practices and the lack of which effectively prevents us from achieving any such goods' [11]. He regards such virtues as defining the relationships between people who share the purposes and standards of a practice. He further regards truthfulness, justice and courage as being prerequisite virtues for any practice, providing the following explanation for the somewhat unexpected inclusion of courage: 'We hold courage to be a virtue because the care and concern for individuals, communities and causes which is so crucial to so much in practices requires the existence of such a virtue' [12]. All of this is very relevant to the practice of engineering, but it is necessary for such a purposive practice to extend the definition of a virtue beyond the enabling of the achievement of internal goods to include also the achievement of external goods and goals.

Furthermore, it is possible to identify certain desirable human qualities that are particularly appropriate for the practice of engineering. As noted in Chap. 1, the Royal Academy of Engineering has identified four such 'fundamental principles' that should guide engineers in achieving the high ideals of professional life: *accuracy and rigour*; *honesty and integrity*; *respect for life, law and the public good*; *responsible leadership, listening and informing* [5]. Though these principles may be applied throughout a professional engineer's activities, they are each particularly relevant to differing aspects of his or her work. Thus, *accuracy and* *rigour* are especially relevant to the purely technological aspects of such work, in particular the application of mathematics, scientific knowledge, and practical know-how. The importance of technological competence is strongly emphasised. The requirement for *honesty and integrity* becomes particularly relevant in the business dealings of engineers. This can be challenging for an international activity such as engineering, for acceptable business standards can vary greatly between different cultures. *Respect for life, law and the public good* is an essential recognition of the profound effects which engineering can have on the flourishing of individuals and the communities in which they live. Proper expression of such respect can demand great care, for the effects of an engineer's activities may have consequences that are very extensive in both place and time. The need for *responsible leadership, listening and informing* arises from the privileged and trusted position in society that results from engineers' specific and high-level expertise. They not only have knowledge and skills which enable the solving of problems and the fulfilment of opportunities, but even more importantly the same knowledge and skills may provide them with an unique ability to identify such problems and opportunities. Thus, it is these four principles which have been recognised as being most important for the specific fulfilment of the practice of engineering. In MacIntyre's terminology they may be considered virtues. The text in the Appendix of Chap. 1 provides further details of how each principle or virtue is to be understood.

Virtues have so far here been considered in the context of the practice of engineering. However, MacIntyre also highlights a specific feature of his view of virtues: 'no quality is to be counted a virtue except in respect of its being such as to enable three distinct kinds of goods: those internal to practices, those which are the goods of an individual life and those which are the goods of community' [13]. The reference to an individual life is important in the present context as it recognises the significance for each individual of achieving continuity and coherence in both professional and personal life [14]. We are human persons always and only sometimes engineers. Such consideration can provide a useful check on the ethical validity of professional activities. The reference to the community is met in the present context by considering virtues as enabling the goal of the practice of engineering.

2.2.5 Institutions

For MacIntyre, no practice can survive for an extended period of time unless it is sustained by institutions, of which he gives clubs, laboratories and universities as examples. Institutions provide an historic dimension, sustaining the continuity and coherence of a practice. Among the important institutions of the practice of engineering are regulatory authorities, university departments, professional associations and commercial enterprises.

The national regulatory authority in the UK for the registration of professional engineers is the Engineering Council. The key professional designation that it awards is Chartered Engineer (CEng). Achievement of this designation typically requires, at a minimum, successful completion of an accredited, 4-year Master of Engineering (MEng) (Hons) university degree course, a subsequent 4-year period of training and work experience, and the holding of a sufficiently responsible position in engineering. The present book uses the term ‘engineer’ in this rigorous professional sense, and the term ‘engineering’ is used to describe the endeavours of such professionals. Such precision is important, for insufficient clarity in the use of these designations and other terms such as technologist, technology, scientist and science is a source of much confusion in society.

Thus, engineers enter the profession through university level education. If engineering is to continue contributing to human flourishing, it is essential to recruit technically able and highly motivated young people with a desire to help others. University engineering courses give high priority to technical competence and require a high level of scientific and mathematical ability for successful completion. However, courses increasingly also include education in engineering ethics, often termed professional responsibility, and substantial effort has been invested recently in providing a focus on ethics as an inherent part of professional engineering activities. Nevertheless, university engineering departments face a challenge in recruiting sufficient numbers of technically competent and ethically sensitive students, as the contribution of engineering to human flourishing may be poorly appreciated by young people. In addition to providing education, university engineering departments help sustain the practice of engineering by being centres of excellence in engineering research, often initiating the research from which the practical innovations of the future derive.

Engineering has a diverse range of professional associations. In the UK,[6] for example, the national academy of engineering is the Royal Academy of Engineering, which fulfils roles comparable to those of the Royal Society in science and the British Academy in humanities and social sciences. The Academy seeks to enhance national engineering capabilities, recognise excellence, inspire the next generation of engineers and lead debate concerning public policy making about engineering. Additionally, there are 36 professional associations representing various sub-disciplines of engineering in the UK, a complexity that has arisen for historical reasons. A few are large, such as those representing civil engineering, mechanical engineering and chemical engineering, and many are small. These make important contributions to sustaining the profession through promoting standards of excellence, improving public understanding of engineering and providing support to both individual engineers and engineering employers.

[6] This paragraph refers to the UK, but comparable professional associations exist in many countries.

Commercial engineering enterprises lie at the core of the practice's ability to provide the material artefacts that promote the flourishing of persons in communities. Some of these enterprises are large multinational organisations employing thousands of engineers as well as many other types of staff. However, in the UK and the rest of Europe there has been a decline in large industries and a growth in more specialised companies, small and medium enterprises (SMEs), leading to changing employment opportunities for engineers. For example, chemical engineers are now less likely to find employment in petrochemical industries and are increasingly likely to work in businesses operating on a more modest scale in areas such as food processing or environmental protection. As employees in commercial organisations, engineers may experience a conflict between their professional values and the requirements of their employers, for commercial organisations are characteristically most concerned with external goods, particularly profit. Resolving such a conflict may require great discernment. However, organisations also exist that specifically aim to take person and community centred approaches to engineering that reach beyond technical issues. For example, Engineers Against Poverty [15], a specialist organisation working in the field of international development, aims to use the skills and resources of the private sector to secure social improvements through mechanisms that also deliver commercial advantages to the companies involved.

2.2.6 Systematic Extension

An important feature of practices is that through such activities the 'human conceptions of the ends and goods involved are systematically extended' [1]. The most familiar extension of the practice of engineering is the continual development of sophisticated engineered artefacts. Indeed, improving the technical aspects of engineering can bring great satisfaction to practitioners. However, this leads to the danger of becoming so absorbed in the technical aspects that the ethical dimension, the effect of the technology on others, is neglected or lost. The avoidance of this danger can be stated as a positive challenge to engineers: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?* The present book is especially concerned with exploring the systematic extension of engineering in such ethical terms.

In this context, it is important to emphasise that a successful practice pays appropriate attention to *all* of its key constituent features. A cautionary note is required here. MacIntyre identified the dangers of too great a focus on external goods such as wealth, fame or power. We are all familiar from news media of the disastrous consequences of the reckless pursuit of such goods. In the case of engineering there is an additional and particular danger of focusing too greatly on the external goods of technological artefacts. Too great a prioritisation of the development of technically ingenious artefacts can lead to mistaking the external goods of the practice for the real end of the practice. Furthermore, it might even be possible for a practice to become so distorted in its goods and ends that it should be considered perverse or even evil: it has been suggested that torture may be such a practice [16]. Issues of the distortion and perversion of the practice of engineering will be considered later. For the present, it will be noted that MacIntyre's approach considers goods not only as they are connected with a practice, but also as they contribute to the flourishing of the whole lives of those participating in the practice and the flourishing of the broader community affected by the practice. That is, an individual person's life should have an overall coherence and a community's range of practices should harmonise.

2.3 An Opportunity of Professional Capabilities

The goal of engineering has been described as *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. This is expressed in very general terms, as is appropriate for an activity as diverse as engineering. Individual engineers and engineering institutions may seek to contribute to the fulfilment of this goal in many different ways. Their actions will typically involve practical improvements to presently existing circumstances, using their unique engineering capabilities to identify and implement such improvements. If engineers are to seek real innovation in the acceptance and expression of ethical responsibility, it can be beneficial to have an aspirational approach to the prioritisation of such activities. It may be proposed that a useful guide for the choice of such actions can be formulated in terms of an *opportunity of professional capabilities*:

> …if some action that can be freely undertaken is open to a person (thereby making it feasible), and if the person assesses that the undertaking of that action will create a more just situation in the world (thereby making it justice-enhancing), then that is argument enough for the person to consider seriously what he or she should do in view of these recognitions.

This formulation was used to define an *obligation of power* in Sen's account of political justice [17]. However, engineers rarely have the type of political power referred to by Sen. It is, therefore, proposed here to retain the definition but to refer instead to an *opportunity of professional capabilities*. Such opportunity could be considered as a generalisation of the 'rule of rescue': the compelling motivation to save endangered human life wherever possible. When we become aware of the need of others we are almost always free to walk away. Nevertheless, we are often moved to action by the challenge that confronts us. Such action is an ethical act, 'a response to the being who in a face speaks to the subject and tolerates only a personal response' [18], as was discussed in Chap. 1.

It should also be noted that this opportunity is practical rather than idealistic, for it concerns the serious consideration of feasible options and thus recognises that there may be situational constraints on the action (at least initially). The *opportunity* certainly refers to a type of situation in which many engineers may find themselves, for they have at their disposal a range of knowledge, skills, techniques and technologies of great potential. Most importantly, as noted previously, the same knowledge and skills may provide them with an unique ability to identify such problems and opportunities. The term *capabilities* has already been introduced as referring to the various things that a person manages to do or be in leading a life, including *agency*, the possibility to advance whatever goals and values a person has reason to advance. That is, agency gives attention to the person as a doer. Here the term *professional capabilities* is taken to refer specifically to the professional actions which an engineer can undertake to remove injustice and to promote justice.

An *opportunity of professional capabilities* can provide powerful motivations for seeking to promote the flourishing of persons in communities. In particular, it can help guide the systematic extension of the practice of engineering in ethical terms. It is consonant with both engineering and Sen's approach to ethics, each of which seeks to further *practically* the wellbeing and agency of persons in whatever circumstances they find themselves. Furthermore, it will be argued in later chapters that sometimes the circumstances of persons and communities may be so dire, and the capabilities of engineers so apt, that it is more appropriate to consider an *obligation* of professional capabilities.

However, it will be helpful at this point to illustrate how the analysis presented so far may be applied. Thus, the next section considers the activities of a pioneer of an innovative type of engineering.

2.4 Sidney Loeb: His Engineering Work and an Ethical Analysis

In the second part of the last century, there was an urgent need to find ways of producing drinking water from saline water. Sidney Loeb's[7] paradigmatic contribution to meeting this need began with his work on a technical problem. Separation from liquids of small entities such as colloids, macromolecules and simple ions (salts) may be achieved using a type of advanced filter known as a membrane that contains appropriately sized pores, typically in the range 100 nm to less than 1 nm (a simple ion is typically ~0.5 nm in diameter in solution).[8] This raises a number of initial technical issues, two of the most important being: (i) How can large areas of membrane containing such tiny pores be fabricated? (ii) As the

[7] Engineers among the readers of this book may have had the pleasure of knowing Sidney Loeb, who died aged 91 in December 2008. The outline of his work given here is provided for those unfamiliar with his achievements.

[8] One nanometre (nm) is one thousand millionth of a metre (10^{-9} m).

hydraulic resistance of a pore increases very rapidly with decreasing size,[9] how can a practically useful membrane be fabricated?

The key to solving these and other issues was the invention in 1959 by Loeb and Srinivasa Sourirajan of polymeric anisotropic membranes, that is, polymer membranes in which a thin porous layer (say ~1 μm thick)[10] with the required separation properties was supported on a thicker layer with much larger pores. If such a structured membrane (comprising both layers) is then itself appropriately supported, it can withstand the high pressures (up to as much as 80 atmospheres in some cases) required to force purified water through the pores whilst retaining salt. By such means, salt may be removed from water at a useful rate, thus allowing the production of drinking water from brackish water and even from seawater. The first Loeb and Sourirajan membrane was what is now termed a reverse osmosis membrane, and is the prototype of a family of membranes, also including nanofiltration membranes and ultrafiltration membranes, with pores in specified segments of the range from sub-nanometre dimensions to about 100 nm.

Sidney Loeb was known as a man of great ethical integrity, much concerned about human flourishing. He was thus motivated to play a key role in applying his invention through the development of the world's first commercial reverse osmosis system in the town of Coalinga in California, a development that required the ingenious solution of several practical engineering problems. The process at Coalinga provided 19,000 l of drinking water daily for the residents; there was a special need for such provision as the local water was so high in minerals that drinking water was previously transported in by rail tanker. He subsequently moved to Israel, and worked on that country's first reverse osmosis plant at Kibbutz Yotvata, which used locally manufactured membranes to produce 150,000 l of drinking water daily. This installation was important as the local water was sufficiently brackish to pose a serious threat to health when consumed. Throughout his life, he continued to support the commercialisation of membrane-based water treatment processes throughout the world.

The reverse osmosis business that Sidney Loeb pioneered is now worth many billion euros annually. Installed reverse osmosis processes produce in excess of 13.5 billion cubic metres of drinking water annually and are now the leading desalination technology on a world basis. Additionally, more than 17,000 small industrial, ship-mounted and household reverse osmosis systems are also in use. Furthermore, the closely related processes of nanofiltration and ultrafiltration are very widely used throughout the manufacturing industries, including pharmaceuticals and food production. Such membrane processes also have important medical applications.

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[9] Assuming constant fluid viscosity, hydraulic resistance is directly proportional to the length of a pore and proportional to $(1/\text{pore diameter})^4$. A further increase occurs due to the increased viscosity of water in pores of nanometre dimensions.

[10] One micrometre (μm) is one millionth of a metre (10^{-6} m).

It is now possible to consider Sidney Loeb's work in the philosophical framework described earlier. Thus, in terms of MacIntyre's description of a *practice*:

End/Goal—Sidney Loeb made clear in many conversations, lectures and actions that he was motivated by a compassionate concern for the flourishing of those within his community and outside the boundaries of that community.

Internal goods—Discovery (with Srinivasa Sourirajan) and recognition of the importance of membranes with an anisotropic structure; ingenious solution of practical engineering problems in the design, cost-effective construction and safe operation of the world's first commercial reverse osmosis plant at Coalinga in California.

External goods—Successful construction and operation of the plant at Coalinga and the subsequent plant at Kibbutz Yotvata, both meeting essential local needs; continued support for commercialisation of membrane-based water treatment processes to billion-euro status.

Virtues—The key engineering virtues were apparent throughout the development of this work: accuracy and rigour; honesty and integrity; respect for life, law and the public good; responsible leadership, listening and informing.

Institutions—Many have arisen to support the practice: research centres (including Srinivasa Sourirajan's), technical journals and commercial companies.

Systematic extension—Development of all of the key features of this part of the practice of engineering continues. An important current priority is the development of low cost systems for impoverished communities.

Further examples of the benefits to persons, external goods, may be made clear in terms of Sen's concept of *capabilities*:

Wellbeing achievement—Improved health due to the provision of high-quality drinking water.

Agency achievement—Improved health allows adults to take a fuller part in society and ensures that children are well enough to attend and fully benefit from school: these are just an indication of a multitude of such benefits.

Wellbeing freedom—Benefits continue to increase as membrane engineering provides for the growing worldwide need for high-quality water—much of the world's population lives within a few kilometres of the sea which thus provides an accessible large resource.

Agency freedom—Options and opportunities continue to arise due to the use of membranes in a multitude of processes including pharmaceutical and food production.

Thus, MacIntyre's and Sen's concepts provide a good framework for the consideration of the engineering development of membrane desalination and related membrane processes. The *agency* benefits are particularly worthy of attention as these are often neglected in ethical assessment of engineering. It should also be noted that Sidney Loeb's work was quintessentially that of an engineer. If he had been a scientist, he might have been content with acquiring further knowledge of the properties of anisotropic membranes. If he had been a technologist, he might have been content with the invention of ingenious laboratory devices incorporating such membranes. However, as an engineer he acted on what we could now express as an *opportunity of professional capabilities*. His success shows that aspirational approaches of this type are practically achievable. Furthermore, he received the benefit of an immensely rewarding subjective internal good, in the words of an appreciation in the *Jerusalem Post*, 'he enjoyed the satisfaction of knowing that he had contributed so much to the welfare of so many, now and in generations to come' [19].[11]

Appendix

Engineering, Technology and Science; Engineering, Medicine and Psychology

In Chap. 1, it was noted that it is important to be aware of the different natures of engineering and technology. It can be also be beneficial to be aware of the different natures of engineering and science. Although engineering, technology and science are most usually characterised on anthropological, epistemological or sociological grounds [21], the concept of a practice allows the suggestion of a philosophical distinction.

Thus, for the case of the engineer, it may be suggested that goals, internal goods and external goods are all important and distinct. For the case of the technologist, it may be suggested that goals and external goods tend to converge (for example, the creation of a technically ingenious device). For the case of the scientist, it may be suggested that goals and internal goods tend to converge (for example, the discovery that results in publication in a prestigious journal such as *Nature*). Such philosophical distinctions are not exact, but they may be considered to identify trends that help clarify confusions.

It may also be helpful to observe that the ethical practice of engineering is closer to the practice of medicine than to the practice of psychology. For example, although medical complicity in torture exists, physicians are reported to have had a more limited involvement than have psychologists in the 'enhanced' interrogations

[11] For further details of Sidney Loeb's life and work see [20].

at the US prison at Guantanamo Bay.[12] Indeed, the chair of the American Medical Association (AMA) council on ethical and judicial affairs has advised, 'Physicians must not conduct, directly participate in, or monitor an interrogation with an intent to intervene, because this undermines the physician's role as a healer'. In contrast, the American Psychological Association (APA) has taken the view that such an interrogation is a psychological endeavour in which psychologists may have a special role to play, 'Psychology is central to this process because an understanding of an individual's belief systems, desires, motivations, culture and religion likely will be essential in assessing how best to form a connection and facilitate educing accurate, reliable and actionable intelligence'. Again, whereas the AMA campaigns against tobacco use due to the dire effects on health, the APA has taken the view that cigarettes are 'one of a number of products considered to be hazardous'.

The ethical practice of engineering is committed to enhancing the 'welfare, health and safety of all', or otherwise expressed, to promoting the *flourishing of persons in communities*. As a consequence, engineers should be advised not to participate in the design, manufacture and use of equipment for torture or, as discussed in Chap. 1, to participate in the design, manufacture and use of cigarette manufacturing equipment. Such advice is consonant with that given to medical professionals.

References

1. A. MacIntyre, *After Virtue*, 2nd edn. (Duckworth, London, 1985 [1981]), p. 187
2. A. MacIntyre, A Partial Response to My Critics, in *After MacIntyre*, ed. by J. Horton, S. Mendus (Polity Press, Cambridge, 1994), pp. 283–304
3. D. Miller, Virtues, Practices and Justice, in *After MacIntyre*, ed. by J. Horton, S. Mendus (Polity Press, Cambridge, 1994), pp. 245–264
4. W.R. Bowen, *Engineering Ethics: Outline of an Aspirational Approach* (Springer, London, 2009)
5. Royal Academy of Engineering, *Statement of Ethical Principles* (RAE, London, 2007)
6. M. Sandel, *What Money Can't Buy. The Moral Limits of Markets* (Allen Lane, London, 2012), pp. 114–120
7. A. Sen, *On Ethics and Economics* (Blackwell Publishing, Oxford, 1987)
8. A. Sen, *The Idea of Justice* (Allen Lane, London, 2009)
9. Sen, *On Ethics and Economics*, p. 61
10. M.W. Thring, *The Engineer's Conscience* (M.W. Thring, Brandish, 1980), p. 232
11. MacIntyre, *After Virtue*, p. 191
12. MacIntyre, *After Virtue*, p. 192
13. MacIntyre, A Partial Response to my Critics, p. 284
14. W.R. Bowen, *Engineering Ethics*, pp. 78–80
15. http://www.engineersagainstpoverty.org/. Accessed March 2013
16. E. Frazer, N. Lacey, MacIntyre, Feminism and the Concept of Practice, in *After MacIntyre*, ed. by J. Horton, S. Mendus (Polity Press, Cambridge, 1994), pp. 265–282

[12] All quotations in this paragraph are from [22].

17. Sen, *The Idea of Justice*, p. 206
18. E. Levinas, *Totality and Infinity* (Dudesque University Press, Pittsburgh, 1969), p. 219
19. J. Preiss, In appreciation: Sidney Loeb, desalination pioneer, *Jerusalem Post*, 17 Dec 2008
20. RO's Founding Fathers, *World Desalination Report*, Vol. 44, No. 45 (2008)
21. S.V. Monsma (ed.), *Responsible Technology* (Eerdmans, Grand Rapids, 1986), pp. 13–17
22. K. Pope, T. Gutheil, The interrogation of detainees: how doctors' and psychologists' ethical policies differ. Br. Med. J. **338**, 1178–1180 (2009)

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