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Nanotechnology, Aims, and Values

Ludovica Lorusso
Scienze Politiche, Scienze della Comunicazione e Ingegneria dell'Informazione
Università di Sassari
lorusso@uniss.it

ABSTRACT
This paper seeks to understand the importance of adopting an ethical framework based on values in the socio-ethical discussion on nanotechnology and generally on emerging technologies. In particular, within such framework it is introduced a distinction between two ideal types of science, defined on the basis of their different aims. Such distinction is considered to be a useful guide in the ethical debate on the technological development of our society, because it may help to understand what are the values of science and their relations with our values as members of the social community. My point is that a reflection on the values of science is needed to make scientists aware of their responsibilities as scientists in the society. Once scientists have understood their responsibilities as scientists they could be involved in a broader ethical reflection on their responsibilities as citizens. Technological development makes sense only if intended as an evolution of socio-technical systems and it is not possible to make an ethical evaluation of such evolution without having established what are our values and our idea of a common good. For these reasons nanotechnology should deal with our values, our idea of a common good, and our being responsible as citizens.

KEYWORDS
Nanotechnology, nanoscience, emerging technologies, values, socio-technical systems

1. *Different aims of science*

"Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good; and for this reason the good has rightly been declared to be that at which all things aim" (Aristotle, *Nicomachean Ethics*, Book I).

Three terms are mostly used in the scientific and philosophical literature of nano: nanoscience; nanotechnology; nanotechnolog*ies*. The terms "nanoscience" and "nanotechnology" are mostly used interchangeably, due to the inextricability of scientific and technological research converging at the nanoscale[1]. However, nanotechnology/nanoscience are not considered

[1] There are obviously some exceptions, as for example Tiefenauer (2006).

synonymous of nanotechnolog*ies* (plural), nanoindustry and nanoengineering.

There are *two* main types of contrast in the literature between nanoscience/nanotechnolog*y* on the one side and nanotechnolog*ies* on the other side: in the first case the contrast is founded on *the different goal* that nanoscience/nanotechnolog*y* and nanotechnolog*ies* respectively have, and in the second case the contrast is founded on the specification of the research topic, from a *general* nanotechnolog*y* to many specific *applied* nanotechnolog*ies*.

Here we have an example of the first kind of contrast:

> Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale (Royal Society & Royal Academy of Engineering, 2004, p. 6).

A distinction is made between nanotechnolog*ies* that "design" and "product" nano-objects and nanoscience that "studies" and "manipulate" nano-objects. As for the second kind of contrast:

> Nanotechnology, in the singular, is perceived as a unified program of research; an ideograph, a unique scheme of innovation, which informs the framing of ethical issues and expectations of these technologies. Nanotechnologies, in plural, consist of the applications of this new technology within their different contexts, such as, for example, the life sciences ('nanobiotechnologies') or medicine ('nanomedicine'). In entering these fields, nano can be re-shaped and assumes different connotations because it is oriented toward particular goals (Ferrari 2010, p. 30).

While terms like 'nanoengineering', 'nanoindustry' and 'nanotechnolog*ies*' refer to different levels of application of nanoscience or nanotechnology, the terms 'nanoscience' or 'nanotechnology' refer to a general idea of science at the nano level. What is it hidden behind this difference in the use of terms? My idea is that behind such different use and perception of terms we can find two different conceptions of technoscience, which can be defined by means of their different aims. Looking at the recent history of science, we may see that both philosophers and scientists have felt the necessity of making some kind of distinction between different concepts of science, like the distinction between *science* and *technology*, *basic science* and *applied science*, and so on.

Popper (1935) made a distinction between pure theoretical science and applied science or technology that is still present today in some common images of science and technology; such distinction was based on the *different goals* that were attributed respectively to pure and applied science: he argued that pure theoretical science aims at the discovery and testing of general laws whereas applied science or technology aims to use initial conditions in conjunction with known laws in order to obtain desired final conditions. Agassi (1966) like Popper considered the distinction between pure and applied science as founded on their different ends; however, he also distinguished between applied science and technology, considering the latter to be constituted by applied science and other elements like *invention* and *implementation of the results* of both applied science and invention. Skolimowski distinguished between science and technology in terms of the *concept of progress*, by arguing that "whereas progress in science results from the continuous improvement of scientific theories and consequent enlargement of the scientific store, it is a peculiarity of technological progress that it provides the means (in addition to providing new objects) for producing better objects of the same kind" (Skolimowski 1966, p. 378).

In the '80s the difference between the culture of science and the culture of technology was matter of an intensive debate. At that time philosophy of science and social studies of science were very interested in understanding the differences between science and technology and in analysing their relations in the innovation process. One of the main issues in the debate was the issue of understanding the degree at which technological innovation incorporates basic science. One of the models representing the innovation process was a linear flux from the basic science to the usage, passing through the applied research:

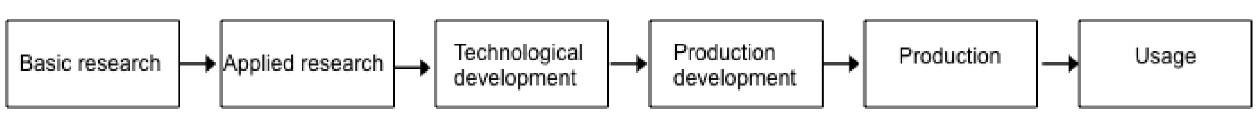

Figure 1. The "six-stage linear model" of the innovation process (Pinch & Bijker 1984, modified).

This model stressed a *linear* relationship between basic research and technological development, considered two steps of a common innovation process. The linear model failed to represent the different relationships between basic research and society and between technological development and society, because it did not consider the feedback mechanism by which the usage of an artefact in a society may influence both basic research and technological development. Moreover, such model considered technology subordinated to basic research under several aspects: chronological, logical, and epistemological. Alternative models like the "interactive model" (Barnes 1982) suggested an egalitarian and interactive relationship between science and technology, where technology was not anymore subordinated to basic science. Such kind of model stressed the independence of technology from basic science as a discipline that creates knowledge as well, even if a different kind of knowledge: a *technological knowledge* vs. a *theoretical knowledge*: technology was considered an autonomous discipline with its own history, its own innovation process, and its own relationships with the society.

In the '90s other kinds of contrast emerged, like for example that between "industrial" and "academic" science: e.g., Ziman (1998) described them as *two distinct cultures* different from a "sociological" point of view, where industrial science represented the culture more involved in ethical considerations about the personal needs and values of customers, patients and other users; such ethical involvement, however, was not at an individual level of the single scientist working in the industrial science, but at the level of the company leading the industrial research. On the other hand he claimed that academic science and scientists working in the academic science did not feel any ethical commitment towards the society, neither on an individual level nor on the broader level of a community. Today a distinction between science and technology does not make much sense, given the fusion of science with technology; moreover, industrial and academic sciences are not so different as they were used to be, if we consider that university laboratories and hospitals are funded by private investors and therefore get a direct benefit in investigating a certain kind of issues and producing a certain kind of knowledge. The worst constraint to freedom is the *selection of knowledge* based on specific interests.

However, my point is that a teleological distinction between two ideas of science still makes sense today and could be useful in the ethical debate on nanotechnology. I propose the following distinction between two ideal types of science:

1. Knowledge-Oriented Science (KOS) that aims to produce scientific *knowledge*.
2. Market-Oriented Science (MOS) that aims to make a *profit* by producing artefacts to introduce into the market.

The different aims of these two ideal types of science make them conceptually and ethically distinct.

KOS has the aim of producing knowledge and therefore searches for *novel* methods, objects, functions, mechanisms, and theories. KOS does not make any selection of knowledge based on specific interests: in this sense KOS is free.

MOS has the aim of making a profit and therefore produces a profitable knowledge by means of searching for *profitable* methods, objects, functions, mechanisms and theories, in relation with the desires and needs of society and the rules of marketing: in this sense MOS is not free to search for *any* knowledge, but only aims at a profitable knowledge. Moreover, its products do not need to be novel, because MOS just follows the rules of marketing: an old scientific product may be sold as a new one, just changing its image or some non-essential feature. An example of the fact the there is no necessity of novelty for MOS products is well represented by the racial drug BiDil. The combination of the active ingredients present in such drug (isosorbide dinitrate/hydralazine) is known from the '80s to treat cardio-vascular diseases in humans: however, from 2005, such combination of ingredients in BiDil has become specific for blacks, since BiDil has been approved by FDA as a racial drug to treat cardio-vascular diseases in African-Americans (Sankar & Kahn 2005). It is clear that BiDil is only marketing and does not represent any scientific innovation.

The conceptual distinction between MOS and KOS highlights different ideal types of science that co-evolve with society through a reciprocal and constant influence. The fact that they are defined by different aims it implies that they have precise and distinct values and responsibilities (see e.g. Jonas 1979). My point is that considering such different values and responsibilities is necessary to establish the role of socio-ethical discussion in science and technology from both a conceptual and operational point of view.

2. *The values of science*

"The absence of a commonly accepted definition of nanotechnologies has precise *epistemological* implications, because it influences the setting and legitimisation of scientific research areas and therefore the scope of the research. The setting of goals clearly has *ethical* implications, because goals and aims are shaped by society and because goals are matters of research policy—in particular through priority-setting" (Ferrari 2010, p. 30).

To find a unique and unambiguous definition of nanotechnologies has of course a great epistemological and ethical relevance in order to set and legitimate scientific research areas with their specific goals and aims; however, I think that a philosophical analysis of the distinction between KOS and MOS has a great relevance as well either in the epistemological and in the ethical debate. Distinguishing between these two ideal types *of science* may be very useful in particular to the ethical debate about an emerging technology like nanotechnology, because emerging technologies attract more private interests with respect to non-emerging technologies. The distinction between the two ideal types of science should be conceived as fluid in the sense that it changes in relation to many variable factors, as for example the amount of economic interests at stake. What is important to remark is that the two ideal types of science are differently related to the *values* we think science should be inspired and regulated by. Consider, for instance, *freedom*. It is evident that both KOS and MOS can claim to be intimately connected to the value of freedom. Nonetheless, the particular way they can do it is different - and this difference has crucial and interesting consequences on our ethical appraisal of their nature and their position within democracy, society, law and the other spheres of collective life.

Recent interviews made to academic researchers during some experiments of interdisciplinary engagement (Schuurbiers 2011) show clearly that they feel that their work should be free of any particular interest. At the question whether the society benefits from their research the common way of answering was: "I hope so. *It's not my immediate goal*; I haven't thought much about it. What I'm doing is basic research; this is probably a little bit far away from … What I'm doing is *too far away*" (Schuurbiers 2011, p. 782).

The paper reports a general picture that emerges from such interviews in which "the ultimate benefits of research *cannot* and *should not* be accurately predicted. Participants gave several historical examples of knowledge flowing from basic research that only much later turned out to have practical use" (*ivi*). Another researcher claimed: "If you invest more in society-improvement, then the learning curve of science will become less steep. So … in the end it's less good for science … And in the end maybe also for society … in the long term" (*ivi*).

From these interviews clearly it emerges that KOS has a specific relationship with the value of *freedom*. KOS's freedom is expressed, among other things, as the absence of a *direct* and *immediate* dependence on the societal consequences; the aim of KOS *should not* be to benefit society at first, but it should be to produce an unrestrained knowledge; only through the process of producing knowledge - indirectly - society will benefit of scientific research. Although it is arguable that society will eventually benefit from scientific research, it is a shared image of KOS that it is *free* in the sense that its goals should not be affected by any pressure depending on society and its immediate needs. In order to ethically evaluate KOS, then, we have to decide what we collectively ethically think about *this kind of freedom* (or, this way of being free). In fact, such freedom may require some kind of indifference towards society; and our ethical evaluation of KOS must evidently include an ethical evaluation of this aspect of its being *free*.

While KOS aims to produce unrestrained knowledge, MOS searches for a profit: and a profitable knowledge ready to be applied and introduced into the society is the means for reaching a profit. Its goal being different, MOS cannot be said to be free (or, demanding to be free) in the same way KOS is. No doubt that MOS is in principle more concerned about societal needs and desires: under this respect, it is more careful about what we need and what makes us happy. Its being less free to investigate topics that are not expected to bring immediate societal positive consequences is indeed required by its secondary goal of *making us more free*, through satisfying more of our desires. So after all MOS is related to the value of freedom in a very different way with respect to KOS. People working in MOS are free to earn money (profit being MOS' primary goal), and people living in societies affected by MOS get free to satisfy a larger number of preferences and needs. How do we value these aspects of freedom? Our ethical evaluation of MOS will surely be different from our ethical evaluation of KOS. That is why I think that distinguishing the KOS and the MOS ideal types of science is useful and even necessary in order to develop a clear and consistent ethical evaluation of science. And, of course, this is even more compelling for nanoscience and nanotechnology, where goal-deriving differences are stressed by fast progress, huge funding, and business competition.

Once we admit that ethical considerations vary in dependence of ideal-typical goals of MOS and KOS, we could nonetheless claim that such ethical considerations are trivial. For instance, we could say that what really counts is that MOS can benefit society more and faster than KOS. But not all technological products are a response for some need of society; most of them are indeed produced to *create a new need* (a new cream for wrinkles, a new TV system, etc.). And we must discuss whether it is ethically blamable to give opportunity to satisfy a greater number of desires or needs via creating new desires and needs - even more than those that will be satisfied. This is an ethical issue directly regarding MOS, and KOS is only indirectly touched by it - as long as KOS may indirectly make MOS and its consequences possible.

Another fundamental value of KOS that lacks in MOS is the *sense of a scientific community*, the idea of the existence of a network of free scientists who collaborate for a final common goal of knowledge. This aspect of KOS is well described by Ravetz (1971), when he talks about the factors that characterize the concept of "industrialisation of science" and one of them is the loss of a network of "informal and personal contacts binding a community". Competition prevails over collaboration, and the idea of a collective human activity disappears. Moreover, for Ravetz industrialisation of science "brings into science the instability and the rapid, uncontrolled changes reflecting the world of trade and industry in our society". The idea of a scientific community as a community of free scientists who share the goal of reaching a free knowledge can be compared with Sandel's idea of a community of free individuals who cooperate for the common good (see Sandel 2009).

Here we have a clear opportunity to see why KOS is rather an ideal type than an objective sociological reality. In fact the academic research system is not the same thing as KOS - distances from KOS being greater or smaller depending on local variances having to do with economical, social, political and technological geographical differences. *De facto* academic scientists do compete for funds, laboratories, jobs, teams, chairs, leaderships, visibility, publication, prizes, glory, immortality, and many other things. So *de facto* the ideal of a human scientific community struggling for the common goal of conquering true knowledge is seldom purely realized. Still this ideal goal affects both their activity and our way of ethically judging it. What I mean is that, for example, we find that an academic scientist who does not collaborate with her colleagues and does not prevent them from taking a wrong way in their research is violating some prescriptive norms ideally regulating her profession, so that we judge her more ethically blamable than an industrial scientist acting in the same way. Of course the problem of private funding of academic research is a very delicate point under this respect, considering that it also affects the scientists' freedom. As long as freedom of academic researchers is limited because of the expectations of the private investors, government funding should be strengthened in every country; the academic research system could still benefit of a co-participation of private funding, but not the whole amount of the money should come from private institutions.

On the other hand MOS has the goal of selecting only the profitable knowledge, which is the only one that can be applied and transformed in a product to be sold. The monetary profit of MOS is meant to be for few people and not for everyone. The societal benefit is a secondary and perhaps unintentional consequence (Adam Smith and the 'invisible hand' debate) of the primary goal of profit. Could MOS choose to produce a kind of knowledge to improve the quality of life of everyone without producing any income for who is paying for the research? No, because the goal of MOS is to make a profit. However, an utilitarian may conclude that after all MOS as an ideal type - and all its closest realizations - are ethically better than any KOS, just because MOS is more likely to maximize general happiness than KOS. A communitarian, on the other hand, may argue that KOS is better than MOS, for very different reasons. Consequently, the utilitarian and the communitarian would ethically prefer different *real* scientific groups, enterprises, systems, organizations and so on. But *the reasons* why they would differ in ethically evaluating such *real things* are much clearer if we firstly understand why they differ in ethically evaluating the ideal types of MOS and KOS, and secondly ascertain how those real things are close or far from realizing the ideal types of MOS and KOS respectively. Using some regulative concepts turns out to be very useful for applied ethics - and specifically for nanoethics. My proposal may also be seen as that of introducing a teleological, goal-dependent distinction within the well-known notion of *socio-technical system*: such old concept (see e.g., Bijker, Hughes, and Pinchs 1987) is very used today in the literature of social studies of science to stress the impossibility of isolating technology from society (see e.g., Johnson 2007; McGinn 2010). The notion of socio-technical system emerges from the interactions between technoscience and society: by introducing the conceptual framework of the two ideal types of science we must consider the different socio-ethical issues emerging from such distinction that influence the change of socio-technical systems. KOS and MOS produce different kinds of knowledge that influence in a different way the evolution of socio-technical systems.

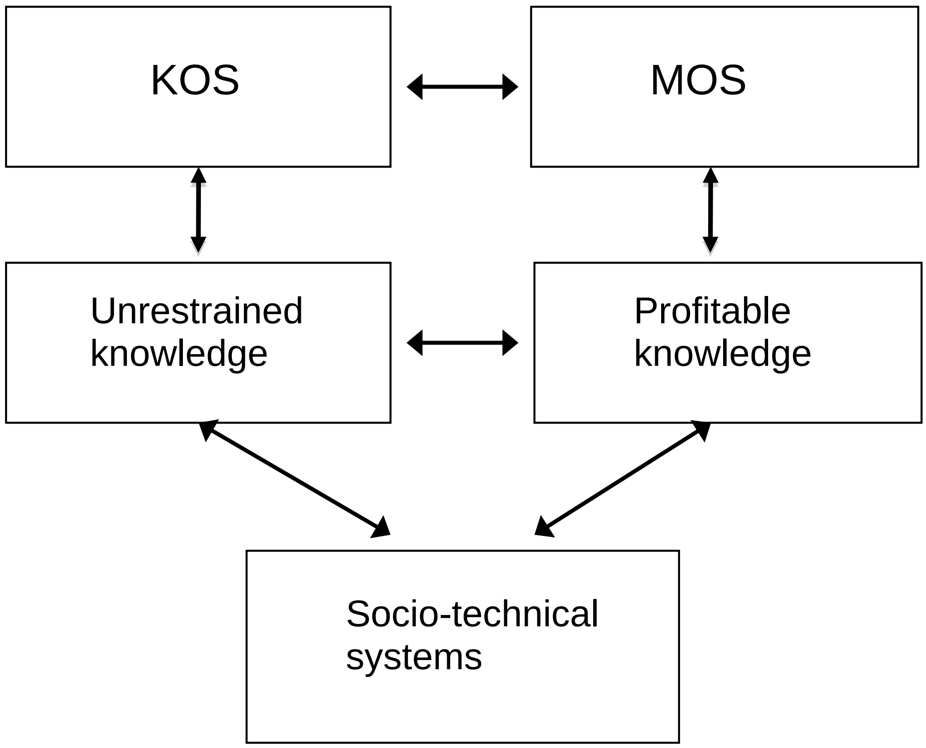

Figure 2. The evolution of the two ideal types of science and the socio-technical systems.

The model[2] above sketches the net of the mutual interactions between KOS, MOS, and socio-technical systems. Compared to the model of developing technological knowledge in Fig.1 there is no linear process that produces "technological innovation": the two ideal types of science and socio-technical systems participate in a open causal net and co-evolve together. The term "evolution" is used here instead of "innovation", since as I claimed MOS does not produce necessarily "new" scientific objects but new products (sold as "new" following a marketing strategy) and on the other hand KOS in-

[2] The model does not aim to represent exhaustively the complex framework of the relations between KOS and MOS, but it aims to offer a schematic suggestion of the main interactions involved in the "circle" of socio-technical systems evolution.

volves a slower process of production than MOS, which for a long period could produce no novelty. Moreover, the word "innovation" stands also for "progress" and it is not straightforward today individuating what is a socio-technical system progress: socio-technical systems are complex structures, and the idea of progress of socio-technical systems supposes some high-order goal the whole process is aiming to. But there is no guarantee that any more recent socio-technical state is objectively *better* than any older state, or that any more recent human lifestyle made possible by technological development is objectively better than any older lifestyle, and so on (MacKenzie & Wajcman 1999; Sandler and Kay 2006; Johnson 2007). We would need to fix some objective evaluative measure, which is highly problematic. We can of course say that, relatively to a particular point of view or interest or preference, some process is an improvement. But assuming that particular point of view or interest or preference is clearly not required. The same holds for natural evolution, where we can say that human beings are "better" than amoebas just if we agree to assume some particular point of view. The word "evolution" is therefore appropriate because the is no necessity of advancing to a better state, and also because it signals for the complexity of any cultural evolution, in this particular case an evolution that also involves processes of adaptation of society and/or its parts to new technological opportunities and vice versa. In such evolutionary process KOS and MOS are not separate paradigms that do not communicate to each other; they are involved in reciprocal interactions and are both embedded in complex cultural processes.

Considering the interactions between KOS and MOS, on one side, and society, on the other side, there are of course many ways in which such interactions could deploy. How can society affect KOS and MOS? There appears to be a continuum between cultural, ideological, soft, bottom-up kinds of affections on one hand, and legal, coercive, hard, top-down kinds of affections on the other hand. The latter typically occur through regulation, ban, moratorium, permission, deregulation; the former take place via cultural change. If we focus on the softer, cultural ways in which society can influence the direction of socio-technical evolution by affecting KOS, we can stress at least two main possibilities:

1) Influencing models, hypotheses, concepts. Science is a human activity and therefore it is embedded in the cultural and social context (Kuhn 1962). Society can affect its shape and contents, its problems and urgencies, its direction and development.

2) Influencing a re-conceptualization of science with specific aims and values. Society can transform science by changing our ways of thinking of it - included our ways of conceiving our values and seeing the relationships between our values and KOS, by means of realizing, neglecting or violating them. Such an influence takes place on multiple levels: politics, institutional discussion, media, habit change, etc.

Similarly, society has some different options in order to shape the direction of socio-technical evolution by affecting MOS on the softer and cultural end of the continuum:

1) Making choices about the usage of the products. Society can make choices about the usage of objects that could change the market and consequently the directions of MOS.

2) Influencing our relevant values, and the ways we see the relationship between our values and MOS. This has a feedback on how scientists working in MOS conceive themselves, too. The general location of MOS in our moral view of human activities, and the capacity of MOS to auto-regulate is at stake. Another point is how similar to the scientists operating in KOS the scientists working in MOS feel to be.

The development of nanotechnology may be made responsible only through the active participation of the society. The *direct participation* of the society in the socio-technical evolution involves today activities of multidisciplinary engagement for scientists and the public. Such activities are not intended in a negative way, *to limit or control* nanotechnological innovation. Otherwise, they are intended in the positive sense of "preparing" the public to receive such innovation and of improving in scientists the awareness of the socio-ethical implications of their work.

1. Public Engagement (PE) activities. Within the emerging framework of discourses regarding social and ethical issues of scientific research and the relationships between science and society, in the last years the figure of the *public* entered into the "Societal Dimensions" component of the National Nanotechnology Initiative (NNI) in the United States, which has the achievement of linking "basic science" to "societal benefits". Such entrance has been accompanied by an emphasis on activities related to "public understandings of nano", "cultivating public trust", and "public interaction and outreach" (see e.g., Viseu & Maguire 2012). While one part of PE should involve people in an active participation and discussion about the values of science, another part should involve a reflection about their needs and values as members of the society. To realize such kinds of participation is not an

easy and quick process and certainly is not a process people can do without the help of scientists, philosophers, sociologists, and historians.

2. Scientist Engagement (SE) activities involve scientists in a discussion on the socio-ethical consequences of their actions. Since the '80s the sphere of social responsibility of scientists includes a critical reflection on the socio-ethical context of their work (see, e.g., Verhoog 1980; Ziman 1998). Firstly scientists must feel responsible for what they do everyday in the laboratory; they should be able to evaluate the societal relevance of their research; then, they must feel part of the society not as scientists, but as members of the social community. Therefore, one aspect of the ethical engagement of scientists consists in an ethical reflection of their work and in improving the sense of an "internal" ethics in the form of a set of ethical norms and principles that are considered necessary to be a "good" and "responsible" scientist; they must understand their part as scientists in changing the society. The second aspect, more complex, consists in "making" scientists citizens who feel the responsibility to contribute with their actions to the common good. Scientists must feel part of a broader moral community, the social community; only if they feel members of such community they will begin to understand that to be involved in the socio-ethical debate is their responsibility exactly as the public, that being involved in such debate is a matter of care and not an obligation (see e.g., Puig de la Bellacasa 2011). SE projects should work hard in this direction, since it seems the only way we could dissolve the dichotomy between science and society, or science and public. According to recent interviews (i.e., Viseu & Maguire 2012) most scientists believe that it should be the public to reflect on socio-ethical issues of technology, because such issues are outside the realm and responsibility of "proper" science: "Scientists can give you answers and can give you options, but it's really up to the public to decide what's the correct course" (Viseu & Maguire 2012, p. 200). Other interviews (i.e., Schuurbiers 2011) reveal that several scientists think that it also is up to the public to decide about what research topic should be investigated (and funded): "politicians are the voice of the people, and those are the ones that automatically decide who gets the money, because they should have, they should know, what people want. So if people want cleaner fuels, then they give money to cleaner fuel. If people wanted better dogs, than they would find someone else. I think it's driven like that" (Schuurbiers 2011, p. 783). Again, I think the ideal-typical distinction between KOS and MOS is useful to face the general problem of shaping PE and SE activities.

3. ***The relationship between science and society: making science trustable***

I want to focus on three requirements for the future relationship between science and society, which nanoethics should care about. The first requirement is *making science trustable*.

In order to promote an active role of the society in the evolution of socio-technical systems we need a *transparent and trustable science*: a transparent and trustable science can be reached with a co-operative open network between laboratories in which step by step reports of the experiments and periodical reports of the directions of research are mandatory. Such research network must link every laboratory in the world. In this way we would promote the transparency required for a good communication between science and society and a right development of the scientific community. Laboratories would have to share not only *favourable* results but also *unfavourable* results; such precise request has been already formulated several years ago by physicians for clinical trial registration:

> Altruism and trust lie at the heart of research on human subjects. Altruistic individuals volunteer for research because they trust that their participation will contribute to improved health for others and that researchers will minimize risks to participants. In return for the altruism and trust that make clinical research possible, the research enterprise has an obligation to conduct research ethically and to report it honestly. Honest reporting begins with revealing the existence of all clinical studies, even those that reflect unfavourably on a research sponsor's product. Unfortunately, selective reporting of trials does occur, and it distorts the body of evidence available for clinical decision making (DeAngelis et al. 2004).

Sharing unfavourable results is an important value in science which is specified in KOS's goal of searching for *any* kind of true knowledge: profitable and non profitable, favourable and unfavourable, advantageous and disadvantageous. The choice to select only some kind of knowledge and to hide another part considered non convenient for private interests is morally blamable because any knowledge may contribute to scientific progress. It is evident in the case of clinical trials because, as pointed out by DeAngelis et al., it represents an egoistic and dishonest behaviour towards all individual volunteers who decide to participate because they trust that their participation will contribute to improve other people's health and that researchers will minimize risks to participants. It is less evident why it should be considered morally blamable in science in general, but we may suspect this is so only because we are not used to reflect on the values of science; again, the distinction between KOS and MOS is helpful to clarify what such values are.

If we establish that a community of free scientists who search for a free knowledge is what we think science should be, to share unfavourable results in scientific practice becomes highly morally relevant. Being a KOScientist brings precise responsibilities, and to publish both favourable and unfavourable results of a research represents one of these responsibilities. Indeed the moral requirement of sharing favourable and unfavourable knowledge is part of our concept of KOS. This is a moral requirement that every KOScientist should match.

Of course the same does not hold for MOS. Although it would be obviously a good thing that a network be built among KOS laboratories in order to share knowledge, we would not say that a MOScientist who does not care about that is as morally blamable as a KOScientist. The reason is that we think that MOS has different intrinsic goals. In other words, MOS is intrinsically less trustable than KOS.

So it is not easy to make MOS trustable, because MOS only searches for profit; MOScientists are not free and can hardly feel *individually* responsible for what they do, because their work is subordinated to some higher business plans. How to solve the problem of trustability in MOS? I think that MOS must be periodically controlled by specific public institutions; through such control procedures the State would make a pressure towards transparency of the whole decision-making process inside MOS, with the final aim of making MOScientists free to be individually responsible as their KOS colleagues. However, making scientists free to be responsible is not enough, since both KOS and MOScientists are not trained for understanding moral issues related to their work: they also need to be helped to get more responsible.

4. *The relationship between science and society: making scientists responsible*
The second requirement I want to stress is *making scientists responsible*.

Indeed we all should agree that "technological revolutions are constituted by significant technological progress; technological progress enables comfort, ease, health, longevity, security and wealth; therefore, technological revolutions are social goods" (Sandler & Kay 2006, p. 675). And dealing with social goods requires a responsibility that goes beyond the responsibilities that scientists may have as scientists: it requires a responsibility as citizens.

Today many SE projects have the precise aim of promoting interactions between science and society, like for example the STIR project[3], and many sociologists and philosophers have developed different approaches aimed at enhancing the socio-ethical dimension of research decision making, as for example, approaches to stimulate the "ethical imagination about the future" of researchers (Van der Burg 2009), approaches that use co-evolutionary scenarios (Robinson 2009), biographical narratives (Consoli 2008), ethical parallel researches (Zwart et al. 2006), and trading zones (Gorman et al. 2004). Engaging in different ways scientists in the socio-ethical debate will increase their sense of responsibility and will make them aware of what are the questions they should ask themselves in the everyday work in the laboratory. The idea is that a scientist should be trained to understand the socio-ethical side of its everyday decisions on experimental design. At the same time, a scientist should be familiar with a broader reflection on socio-ethical issues related to the role of science in the society. This within-lab work will help scientists to develop a reflexive awareness of the immediate ethical implications of their decisions and will reinforce the interactions between the public, scientists, sociologists, and ethicists.

The topics discussed in the STIR studies (see i.e., Schuurbiers 2011) are chosen to enhance a self-reflection on the work of a scientist in the everyday scientific context of the laboratory. Mainstream Modulation (MM) framework represents one of the most known form of STIR and it has been developed and applied in a pilot study by Fisher & Mahajan (2006) with the aim

[3] The Socio-Technical Integration Research (STIR) project is a NSF-funded project conducting a coordinated set of 20 laboratory engagement studies to assess and compare the varying pressures on – and capacities for – laboratories to integrate broader societal and philosophical considerations into their work (Fisher & Guston 2008).

of testing and enhancing the capacity of researchers to integrate the socio-ethical context in their decisions: "As a policy instrument, midstream modulation (MM) is a means of incrementally influencing a technology during the "midstream" of its development trajectories. It thus asks *how* research is to be carried out, which is within the purview of engineering research, rather than *whether* a research project or product should be authorized, approved, or adopted, which is largely beyond the purview of engineering research" (Fisher & Mahajan 2006, p.3). MM can address immediate concerns of worker safety and exposure and can identify opportunities to impact longer term outcomes by means of studying the nature of researcher decisions in the context of the laboratory itself; however, such approach - as declared by Fisher & Mahajan (2006) - has not the aim of addressing the nature of societal concerns. May an approach that does not aim to stimulate among scientists a reflection on issues related to the nature of societal concerns be sufficient to reach the aim of shaping technological trajectories? I think it may not. MM framework lacks of a crucial aspect regarding a broader socio-ethical perspective in the debate on emerging technologies, which I do not think should be considered "beyond the purview of engineering research", as claimed by Fisher & Mahajan (2006).

In particular, the questionnaire in Schuurbiers 2011 - inspired by the MM protocol - is articulated in two main categories of questions: *micro-ethical* questions regarding the reflection on safety rules within the research system, which are very specific (e.g.: "why are you wearing plastic gloves now?" (*ibidem*, p. 775)), and *macro-ethical* questions regarding the reflexion on the research system, which are very generic and embedded in a pure cost-benefit framework (e.g.: "does your research benefit society?" (*ivi*)). Among macro-ethical questions there are also epistemological questions like: "would you say scientific facts describe the world as it is?" (*ivi*). I think that such work certainly represents a first necessary step for scientists to reflect about very short term safety, ethical, and social aspects of their decisions in the experiments, however it lacks to involve scientists into the current debate on the impact of emerging nanotechnology in the society not as scientists but *as members of the society, as citizens*. In other words, current experiments of integration of societal considerations into and during nanoscale engineering research preserve the dichotomy between science and society and by focusing on practical concerns about risk and safety they forget to care about more fundamental values of our society. These limits are both caused by the cost-benefit and risk ethics framework adopted in the current debate. Such perspective represents the real limit for a "responsible innovation" of nanotechnology.

If we consider for example the issue of freedom of science, in Schuurbiers (2011) scientists are pushed to reflect to the fact that academic *science is not free because funded by private investors*. While it is certainly necessary to highlight this aspect, no reflection about the value of freedom of science has been stimulated by the interviewers. Such interdisciplinary works should stimulate scientists to reflect further about their idea of science, their idea of freedom in science, and other values of science. The approach used in the questionnaires weakens the ideal views of scientists instead of enhancing them. Scientists should be stimulated to re-think about KOS, MOS, and the scientific community in the Ravetz's sense of a network of free scientists who aim to produce new knowledge. It is a result to be obtained both at an *individual* level and at an *institutional* level by enhancing public funding to academic research. For a long time science has been embedded in a matrix of non-scientific institutions, but this fact should not be an excuse to forget what the values of KOS and MOS actually are. My point is that scientists are not stimulated to reflect about the reasons *why they say that science should be free* and in which sense they think this freedom should be preserved. The distinction between KOS and MOS may help scientists to reflect on these points.

I think that this issue of MM framework has to be considered just as an example of a way of thinking about ethics, science, and society. A virtue ethics would work much better than a cost-benefits ethics in order to make scientists responsible at an individual level of what they do every day in their laboratories. The goal of influencing scientific and technological development can be reached only outside of a cost-benefit ethics; such goal can be pursued only by making scientists feel as citizens within a social community who reflect on their values and their idea of the common good. Therefore, the topics of the discussion in the STIR project studies should include broader issues like the following: *what are the values you would like to preserve for the future generations? Should every member of the social community be involved in making the common good? What do you think may be your part as a member of the social community? Does your belonging also to the scientific community make you more responsible than any other member of the society?*

Only this kind of discussion will make possible a critical dialogue on socio-ethical issues of nanotechnology in KOS and MOS. The socio-ethical discussion on the responsibilities of scientists *as citizens* may involve scientists in a deep ethical reflection on the difference between individual and societal benefits, and between benefits and common good of the social community: such concepts are very different and to understand such difference is fundamental in order to attribute a significance to the concept of well-being.

While issues related to responsibilities of scientists as citizens are exactly the same in KOS and MOS, we could expect that the concept of responsibility as a scientist is not embedded in the same way in the MOS and KOS context of work. In fact, even once we have made MOScientists free to be responsible during their work as well as KOScientists, still there is the problem of the lack of the *value* of scientific community in MOS. It is quite evident that the fact of knowing to belong to a community naturally reinforces the sense of responsibility.

Recent interviews reveal that scientists either think that it is not their job to reflect on socio-ethical issues or think that a reflection on such issues is already part of their work in the laboratory, just because they consider safety and toxicology issues while they are working (Viseu & Maguire 2012). It is obvious that reflecting about safety and toxicology issues is very important for a scientist, but it is also obvious that it represents a very small part of the whole socio-ethical reflection on the responsibilities of a scientist towards the society.

A broader reflection on the socio-ethical issues in nanotechnology should also take in consideration the current discussion on the "environmental values" in *ecological economy*, the field that studies the relations between economic choices and the environment in order to achieve a coherent vision of a sustainable development of the future (see e.g., Funtowicz & Ravetz 1994; Howarth & Farber 2002). Ecological economy investigates on the ways for embedding in the economic cost-benefit analysis the contributions of the environment to human well-being and the costs that a depletion of natural capital imposes on future generations; by searching for appropriate indicators of the welfare provided directly by the environment, ecological economy tries to establish the environmental values and the costs of the environmental changes. What is our willingness to pay in relation to willingness to accept a compensation for environmental changes?

Besides the immediate relevance of this kind of research topic in the socio-ethical debate on nanotechnology, there is a more basic question emerging from the discussion in ecological economy, which we should consider when dealing with nanotechnological choices that may have relevant impacts on the environment. I am talking about the question whether we should associate quantifiable values to ecosystems or - in other words -

whether we should establish a price for the environment. Among others, Sagoff (1988) claimed that environmental systems are connected to "core social values" that cannot - or should not - be reduced to monetary terms. For Sagoff to give a price to the environment is a mistake. He claims that consumer-product and environmental problems cannot be solved by giving a price respectively to the "commodities" of product safety and environmental pollution: these two goods do not belong to the market and should not be treated as commodities. Sagoff considers some goods of our society not evaluable by means of the methodology and the concepts used in economy: social regulation should reflect community-regarding values that every individual as citizen has to respect. Sagoff's idea that environmental values are misplaced if traded in the market can be extended on several goods like Sandel does in a recent book (2012) where he claims that to give a price to a good that should not have a price and therefore should not be in the market it "corrupts" that good in the sense that it changes its value. Pearce (1993; 1995) argued against the idea that environmental systems can be considered as market benefits and therefore an evaluation of them should be linked to the concepts of willingness to pay for non-market benefits or willingness to accept a compensation for non-market costs: environmental systems provide material and experiential benefits that contribute directly to human well-being, and are associated to fundamental values of humankind. Nonetheless, every day economical decisions are made that are able to change our environment and therefore the environment must be considered in the economic decisions by introducing concepts that help evaluating the benefits for future generations provided by maintaining the structure and functioning of ecosystems, even when such benefits cannot be quantified in economic terms. Therefore, even if we do not want to consider the environmental change as a commodity to buy/sell in the market, we could still try to evaluate the relationship between our values, our idea of well-being, and the environment, in order to influence the direction of the evolution of "socio-environmental systems". Decisions about any human action have to be made only in relation of human values that are not necessarily linked to societal benefits but necessarily with the higher moral concept of common good.

All these considerations clearly play an important role in the decisions about the direction of scientific research and technological development, but they also help us to understand the changing of values and the "rationality" of a technological society (see e.g., Queraltó 2013). In the investigation of socio-ethical issues related to emerging technologies we should consider all the interactions between socio-economic, socio-environmental, and socio-technical systems; moreover, we should study what are the values linked to these systems and how they change.

All such systems and their interactions should be investigated by means of a multi-disciplinary approach, using insights from sociology of technology, innovation studies, history of technology, evolutionary economics, ecological economics, etc. in order to imagine future scenarios and ethically reflect on them. A multi-disciplinary approach can be found in Geels's work (2005), where a multi-level perspective is described, based on insights from sociology of technology and evolutionary economics: such multi-level perspective shows a substantial *co-evolution* between technology and society in the transition towards piped water and personal hygiene: the idea is that any socio-technical transition in the history is the product of a co-evolution of technology and society that involves technological innovations, such as piped water infrastructure, soap, toilets, baths, as well as cultural, political, economic and behavioural changes.

A multi-level perspective should also face the issue of clarifying the significance of concepts like *well-being* and should work on a reflection on the ways science may improve such well-being (see e.g., Alexandrova 2012). In this framework we should also promote a debate about the concept of *societal benefit* within the concepts of scientific and social community both in SE and PE activities. Sure the concept of benefit is strongly related to the concept of well-being and dependent on the culture considered. For example, consider the society of American women consumers, and an imaginary nanotechnological product that makes people tanned in just 5 minutes. For sure such product will likely be considered a benefit by such kind of society and maybe such society will be inclined to undertake the risk of using such product, in particular if who sells the product undertakes the risk. If we now look at the society of Chinese women consumers - which traditionally considers to be tanned unaesthetic - such society will probably not judge such product to be a benefit and will not be inclined to undertake the risk of it. A reflection here has to be made about the fact that it is not so evident what it is a benefit and for whom. What is a "benefit" depends on what society I am considering. Which society? The society of US consumers? The society of rich US consumer? The society of all human beings, consumers and non-consumers?

By depriving science and society of values it is easy to loose control over the socio-technical development. It is too easy to claim that nano-products are among us and therefore we have to learn how to interact with them. The diffusion of nano-artefacts must be controlled by means of a concrete reflection on our ideas of well-being, benefit, needs and values. MOS tries to introduce in our imaginary the idea that nanotechnology will be "a revolution in *quality of life*" (see e.g. Shelley-Egan 2010), that nanotechnology will change everything we know of the world today; why this should be a good thing? Will this new quality of life be better in the sense of being more desirable? By the way, will it be desirable by the major part of us?

Today two main issues related to the introduction of new nano-artefacts into the market are 1) the issue of distributive justice about the distribution of new artefacts (the issue of the nano divide): will this new quality of life be reachable by everyone? and 2) the aspect of safety, risk, and control: the introduction of new artefacts in the market is under examination because of potential risks involved: for example, the REACH initiative in the European Union – the "Registration, Evaluation, Authorisation and Restriction of Chemical substances" – represents one of the first effort to regulate the introduction of artefacts into us and our environment (see e.g. Robison 2011). My claim is that there is too much focus on the way the "new quality" of life will be distributed and on the costs in terms of risks related to such new quality: few people focus on the significance of such quality and risk with respect to our values. We cannot establish what is an improvement in our quality of life and what represents a risk if we do not fix first what are our values.

Finally, in SE activities a deeper reflection on the dependence of KOS on societal institutions is needed, in order to understand how freedom in academic research can co-exist with a private system of funding. Of course the dependence of science from the institution is not a new thing: "The dependence of science on government, the role of organizational constraints, and the intermingling of scientific and technological problems create multiple reward structures which have consequences for the social and cognitive development of science. The technical system, a centrally-administered network of actors oriented toward the solution of a set of related technological problems, is proposed as a concept which reflects this embeddedness" (Shrum 1984, p. 64). However, it seems that nanotechnology - for its being perceived as so novel a science, surrounded by many industrial interests - is bringing a new relevance to this old issue; in a recent paper Simakova (2012, p. 611) explores how a discussion on sociology of expectations regarding emerging technologies may contribute to shaping the future of socio-technical systems by means of considering moves between the categories of "basic science" and "industrial relevance": "The faculty on campus are enmeshed in a complex web of policies of intellectual property rights and ethics (conflict of interest) committees, the terms of which change from year to year. Articulating which entities were involved in regulatory work - funding agencies, government, industrial partners - entailed judgments upon the capacity or desirability of those entities to participate in the governance of nanotechnologies".

5. *The relationship between science and society: eliminating false beliefs*

The third requirement for nanoethics should be *eliminating false believes*.

What do scientists believe about the role of technological evolution realized through socio-technical systems? They believe that technological evolution tends necessarily to promote the common good (see e.g., Sandler & Kay 2006). I have shown that this is a false assumption for MOS, because MOS aims to make a profit and we cannot assume that its products will necessarily improve the common good. What about KOS? Even KOS cannot promise to improve the common good, because new knowledge could bring to socio-technical systems that are not necessarily good or that could yield both good and bad consequences. It is therefore a false belief to assume that technological evolution will tend necessarily to the common good. The elimination of such false belief is necessary to understand the need of a discussion on our values in relation to scientific and technological evolution.

What do scientists think about the possibilities of improving the interaction between society and science?

> The biggest problem is that people don't know enough science. And that's a big problem. And I want to talk to people about science so I really encourage people to take more science. So I'm an educator. I believe in that. I believe firmly that [...] an informed public can make the best decisions about what's important, and these questions about what gene tools to take, what bioterrorism methods to use… Scientists can give you answers and can give you options, but it's really up to the public to decide what's the correct course. So right now in the debates, you name it, on stem cell research, on abortion, and all these things, quite often, it's the lack of scientific knowledge that is limiting.

> It is the [lack of] generic scientific knowledge of the public that is limiting our ability to do a good job (Viseu & Maguire 2012, p. 200).

Many scientists believe that a positive influence of society on scientific development can be reached only if the public knows more science. I think that this is another false belief. Scientists believe that because they belong to a complex societal paradigm in which this is the common way of thinking. Consider for example the NNI in the United States, which has the goal of promoting a development of nanotechnological research that benefits the citizens; NNI does its job by "preparing" the public to receive such new technology and by "educating" the public, instead of focusing in making scientists responsible (see e.g., Sandler & Kay 2006). A *general* scientific knowledge does not count very much because the socio-ethical debate is about our values and our idea of common good. Such debate involves all people as citizens - therefore it should not be intended as a debate of scientists (the "experts") vs. public (the "non-expert") or even of scientists (the "non-experts") vs. nanoethicists (the "experts"); consider for example they way several researchers think about such debate with nanoethicists as an *unfair fight*: "Tennant [Director of Operations, Cornell NanoScale Facility] describes the actual engagement in SEI [Social and Ethical Issues] as an uneven playing field where scientists are at a disadvantage because of their lack of training" (Viseu & Maguire 2012, p. 203).

To think that the debate needs an educated public could make sense in a framework in which it is possible to calculate the immediate effect of the introduction of a new technology in our world, but this is not possible for nanotechnology. From one side the problem is that we are not able to imagine the risk involved in such kind of technology; from the other side, however, there is the fact that to make a prevision of how a technology will change a society is never possible and therefore the knowledge of that technology represents only a small part of the story and what it mostly counts is represented by the knowledge of our values. Of course, it is not a bad thing to know more about science, but it is not relevant in order to establish the responsibilities of science and the directions of science and technology necessary for a "good" development. Scientific knowledge is important but subordinated to the awareness of what are our values and our common good. To increase the generic scientific knowledge of people it does not help in knowing more about our needs and values. Moreover, often we could hear scientists to claim that the public gets "emotional" about emerging technologies and that their emotions represent a limit to the technological progress. Maybe it is true that many people are scared about *unknown negative consequences* linked to experiments and products of emerging technologies; however, it is also true that the way MOS is selling the *unknown positive consequences* of emerging technologies by means of introducing fashionable promises (see e.g., Swierstra & Rip 2007; Shelley-Egan 2010) is "beyond reason" as well, and aims exactly to get people emotional about such kind of unknown positive consequences. Consider for example the following quote about some of the promises of nanotechnology according to Philip J. Bond, US Under-Secretary of Commerce: "reducing or even eliminating pollution through clean production technologies; repairing existing environmental damage; feeding the world's hungry; enabling the blind to see and the deaf to hear; eradicating diseases and offering protection against harmful bacteria and viruses; and even extending the length and the quality of life through the repair or replacement of failing organs" (Swiss Re Centre for Global Dialogue 2005, p. 7). Therefore, what is the "best irrationality" to be followed?

What is necessary for the public to communicate with science is not scientific knowledge, but understanding to be part of the same community. Scientific knowledge is considered necessary only because we still use a framework of the ethics of risk, where ethics is reduced to a cost-benefit analysis (see e.g., Dupuy 2007). We believe that there exists a risk that can be *rationally* calculated, exactly like in ecological economy we think about the possibility of establishing a price for the environment: by assuming the validity of such framework we have to think that scientific knowledge is necessary to reason on socio-ethical issues of nanotechnology, because an evaluation of the risk requires knowledge. As long as we remain prisoners of the ethics of risk framework we will not reduce the distance between science and society: changing the ethical framework is a necessary step to reduce the number of those scientists who think that it is not their business to care about socio-ethical issues and finally to promote an ethically-informed evolution of socio-technical systems.

6. *Conclusion*

I have analysed relevant aspects of the relationship between science and society realized through PE and SE activities. Certainly such activities represent fundamental instruments to construct a good communication between society and science, a way of rethinking about our values and needs; instruments to reconsider the ethical framework in emerging technologies. Interdisciplinary approaches are important in 1) making the process of decision shared and responsible in KOS and controlled in MOS; 2) reasoning about values and responsibilities of KOS and MOS; 3) reasoning about the hierarchy of values and needs for us and future generations. However, PE and SE do not represent the only way of influencing and controlling the evolution of socio-technical systems.

In 1980 David Collingridge said about the difficulty of controlling technology: "Attempting to control a technology is difficult, and not rarely impossible, because during its early stages, when it can be controlled, not enough can be known about its harmful social consequences to warrant controlling its development, but by the time these consequences are apparent, control has become costly and slow" (Collingridge 1980, p. 19).

Interestingly, Collingridge claims that the reason of the "technology's resistance to control" is the "entrenchment": "The adjustment of other technologies to one which is developing, so that eventually control of the latter is only possible at the cost of re-adjusting the technologies which surround it" (*Ivi*, p. 47). Similarly to the Duhem-Quine thesis (Duhem 1906) of the impossibility of falsifying isolated hypotheses, Collingridge sees in the networks between old and emerging technologies the reason why an emerging technology may not be controlled. The concept of "entrenchment" offers itself as a useful concept, but needs to be analyzed with a full understanding of the social processes and the evolution of socio-technical systems. Technologies are meant here to constitute a complex network in which to isolate one single technical object it is not possible: "Technology in its various manifestations is a significant part of the human world. Its structures, processes and alterations enter into and become part of the structures, processes and alterations of human consciousness, society and politics" (Winner 1977, p.6). Winner thinks about the technological process introducing the idea of "adaptation": adaptation of technological systems, in which every system, object, process, structure, material that does not find part in the human world is eliminated. He claims that beyond a certain level the technological development becomes a self-generating, self-perpetuating, self-programming mechanism and human ends become adapted to suit the technological development.

Such images of technology and technological development highlight the importance of the influence of our choices in the everyday life and of the cultural transmission of our values in shaping the direction of the evolution of socio-technical systems. This is the most fine and efficient form of controlling technological development.

Finally, the distinction between KOS and MOS will help all of us to consider different ethical questions about science:

1. What should be the values of science?
2. What should be the aims of science?
3. What are the individual responsibilities of scientists?
4. How should science meet societal challenges, needs, and values?

In order to answer these questions we should 1) change the sense of participation of scientists to the socio-ethical debate in the sense of making them feeling part of a broader moral community that is the social community and 2) go beyond the *framework of the risk*. As Dupuy (2007) claims, ethics should not be reduced to "prudence" in the sense of a rational management of the risk.

What is a risk in an action involves a discussion of the impact of such action on our values. In order to evaluate the impact and the willingness to accept such impact we need to make projections of the future. Any ethical consideration about introducing new objects into the environment potentially dangerous for the humankind and the environment itself should include an analysis of the hierarchy of values of our society. We cannot let any member of our society introduce products in the market that have unknown consequences on our health without having established first whether this is what we need according to our values. We should first think about our values: the knowledge of what are our values undermines the scientific knowledge considered nowadays necessary in order to participate to the socio-ethical debate on emerging technologies. The concept itself of sociotechnical systems makes sense only in an ethical framework based on values. Talking about risk is important but what is a risk depends of how we imagine our future should be. There is no risk assessment without having established what are our values.

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