

ETHICS AND THE COMPLEXITY OF TECHNOLOGY:
A DESIGN APPROACH

MARC J. DE VRIES

1. *Introduction*

In this article I will show how the conceptual framework for analyzing reality as developed in reformational philosophy can help us to get a fuller understanding of the ethics of technology than in popular reductionist views. Thereby I will use Caroline Whitbeck's suggestion that ethical problems should be dealt with as if they were design problems. Reformational philosophy helps us to understand the nature of complexity in design and also how order in this complex chaos can be created by observing the various functions of technical artifacts. In line with the current empirical turn in the philosophy of technology, I will illustrate this by describing a case study: nanotechnology.

2. *Reductionist perspectives on ethics in technology*

“Not the bullet I made kills, but the person that pulls the trigger”. This is a quote from “The man with the golden gun”, one of the James Bond movies in which Roger Moore features as the famous hero. It is spoken by the person who had delivered a set of golden bullets (meant to kill Bond) to Mr. Scaramanga, the main crook in the movie. The quote is typical for an attitude that was, and often still is held by engineers. It expresses the idea that the technology remains neutral until the user comes in. Designing and producing the bullet harms no one. The engineer therefore can not be blamed for what happens with the bullet. His or her only concern is to make sure the bullet is delivered according to the specifications. The engineer's task, and responsibility, ends as soon as the product is ready to function properly. In the 1950s and 1960s this attitude was combined with the opinion that user involvement in the development of new mass consumer products was both unnecessary and undesired. Engineers claimed that they were sufficiently well aware of user' needs. Besides, how could consumers be able to contribute, ignorant as they were of the technological possibilities and conditions? And even if some consumers would turn away from the product, the prosperous economic situation would always allow for competing companies each to have reasonable sales, given the large market. As a consequence, products were developed by engineers, without input given by future users, and without (explicit) ethical considerations. The consumers then were confronted with new products in the development of which they had had no influence, but for the use of which they were held fully responsible. In the early 1970s the silent acceptance of that situation started to end. Economically, consumers could no longer afford to buy any new gadget that was brought onto the market, and they became more critical and more

selective. Also, social concerns about the possible negative consequences of technology increased. Social actors began to seek ways to have an impact on technological developments. An example of that desire was the emergence of Technology Assessment as a scientific instrument to survey all sorts of possible consequences of technology, in order to enable informed policy decisions with respect to those developments.

On the other hand a concern has grown about the consumers' abilities and willingness to deal with technologies in a responsible way. Research studies into consumers' behavior have clearly shown how difficult it is to make them behave more environmentally conscious. In spite of all the information and technological options that are offered, consumers are slow to adopt behavior that would save the natural environment, such as using energy saving devices, separating different types of garbage, or putting off the central heating earlier in the evening. Clearly in the 1990s and later the worries about negative consequences of technological developments have waned and users are not very concerned about the possible damage that is caused by their use of products. This has given rise to an opinion that is almost the opposite of the idea that engineers have no ethical responsibility, namely the idea that the ethic should be taken away from the users and be built into the devices. If it appears that car drivers do not themselves take the responsibility to wear seat belts and drive slower than the speed limit, then design the car in such a way that irresponsible behavior is made impossible because the car will not function without the driver behaving as expected by the law. In practice that would mean: cars will not start if the driver does not wear a seat belt, and cars can not drive faster than the speed limit. Technically this is all feasible. Socially, however, it is problematic. For that reason most people believe in a milder form of this. Designers can put 'scripts' into their designs: elements in the product that suggest certain behavior. The car does not refuse to start in case the seat belt is not used, but it does produce a fairly annoying sound (which can be put off if the user desires so). A red line on the speedometer suggests that the driver should not pass the speed limit, but nothing happens when the user passes that limit. Thus the ethics is partially built into the device, but it is still up to the user to make the real decisions.

Both the idea that the engineer has no ethical responsibility at all and the idea that engineers should be entitled to take over all the ethics from consumers are forms of reductionist views on ethics in technology, and the idea of scripts in devices is a good correction of those ideas. There are, however, more reductionist perspective on ethics in technology that are more subtle, and for that reason perhaps even more difficult to recognize. Increasingly, ethical considerations of technological developments focus on risk calculations. This is in fact a twofold reduction. In the first place there is more to ethics than risks. The question should not only be: what chances are there to be confronted with negative effects? But also one should ask: how should technology be developed in order to have positive consequences. Even further: not only consequences can be considered (that is only one ethical approach, namely the consequentialist), but also personal values (as in a virtue approach to ethics) and

generally applicable rules (as in a deontic approach). There is a second reduction here too: risks are entirely expressed in numbers. Of course risks can be expressed in numbers to some extent: one can calculate the chance that an accident will happen that leads to a dangerous situation in a nuclear power plant. But how can one express in numbers the different types of consequences this has for people? How can one express in numbers the difference between dying instantaneously in the explosion and dying in the course of years as a result of radiation diseases? Is not that a denial of the human aspects in technology? Humans are then reduced to numbers (of casualties).

A fourth reductionist view on ethics in technology is to analyze all ethical issues in terms of moral dilemmas. That often happens when 'classical' cases are presented in textbooks for engineering ethics (see e.g. Harris, Pritchard and Rabins 1995). One of those 'classical' cases is the Challenger spacecraft that exploded only minutes after it was launched. The problem appeared to be a malfunctioning of the 'O-rings' that should have separated the fuel tanks from the rest of the spacecraft. The air temperature at the time of launching was just below the range in which the O-rings were designed to function. It appeared that some engineers working in the company that had delivered the O-rings had been aware of the risk associated with the devices and had expressed their concerns to their superiors, but these concerns had been declined because it would bring great damage to the image of the company and of the whole NASA project when the project schedule would have to be revised and the launching would have to be postponed. These engineers were faced with a dilemma, the textbooks say: they had to choose between being loyal to their company and remaining silent about their findings, and their responsibility for the safety of the astronauts. In this case there is a conflict between two virtues. The same can be said of another 'classic' case in engineering ethics, namely the Ford Pinto. It was known to some of the designing engineers that the gas tank was not sufficiently isolated from the rest of the car and therefore was potentially dangerous, but here too management forced the engineers to continue the development to avoid delay in the prestigious project. In a similar way engineers can be confronted with a dilemma to choose between a low price for a device (which is in the interest of the company) versus better environmental properties (which would be a personal responsibility the engineers feel for preserving the natural environment). In other cases, though, other conflicts may appear, such as a conflict between a personal virtue and a rule in legislation (a non-engineering example of that is the equally 'classic' case of the desperate father who considers stealing the necessary medicine for his child from the drugstore that will not give him the medicine because he can not pay for it). However obvious this analysis of the Challenger case may seem, it reduces the ethical analysis to choosing between two alternatives. It can be questioned whether that is all there is to say about the options that are available to the moral agent.

3. *Ethical issues as design problems*

Reducing ethics in technology to the responsibility of users or to the role of engineers or to risks or to dilemmas is in itself useful if we use it as a temporary focus on a specific aspect of the problem. The reduction enables us to get a deeper insight into that aspect because we abstain from other aspects and thus can be more precise about the aspect in question. It only becomes reductionism when we ‘forget’ to go back to the full reality of the situation after having studied the aspect on which we had focused. It is reductionism, for instance, to claim that the role of users is all there is to be said about ethics in technology. In a similar way, it is reductionism when it is claimed that ethical problems are exhaustively analyzed when we describe them as moral dilemmas. In a recent book on engineering ethics, Caroline Whitbeck has proposed to widen the view on ethical problems by treating them as design problems (Whitbeck 1988). Design problems to a certain extent are dilemmas too. The very core of the design problem often is a conflict between two or more requirements or constraints. A simple example can illustrate that. A designer of household equipment working on a new iron is confronted with a conflict between two requirements: on the one hand the iron should be light so that it is easy to lift and handle, but on the other hand it should be heavy in order to press on the cloth and make it smooth. A good designer will move beyond the level of merely choosing between the two or finding a middle road, but (s)he will seek for creative solutions in which the two requirements are fully reconciled (an example of such a solution might be a vibrating sole, which of course would have other disadvantages but would certainly allow a light weighed iron to press sufficiently on the cloth). In a similar way we have to read Whitbeck’s claim that ethical problems should not be solved by merely choosing between one alternative in the moral dilemma, but by seeking creative solutions that overcome the conflict in that dilemma.

Regarding ethical problems as design problems is one way to emphasize the notion of agency. Glas (2006) pointed out that the notion of agency “opens a dimension of normativity right in the middle of human existence, the dimension of responsibility”. This very much is the case in design. Design cannot be understood without a focus on agents: the designer, but also the user. Also design brings in normativity, as it is by definition concerned with such normative notions as ‘design requirements’, ‘constraints’, ‘good practice’, ‘norms and standards’, just to mention a few examples. Besides, design brings in some other notions that Glas mentioned as important for a Christian perspective on moral issues: elements of play, invention and trial and error (Glas 2006).

This view on ethical problems not only avoids the reductionism of analyzing ethical issues exclusively in terms of dilemmas, but it also helps to avoid the other types of reductionism that we have seen in section 2. That is the case because for design there is an increasing awareness that by its very nature it is an activity in which we can not afford reductionism but we have to work with reality in its full complexity (Sarlemijn 1993). This awareness has begun to increase in the 1970s for the same reason as we have already encountered in section 2. As governments started to express a desire to influence the work of

engineers and as consumers began to be more selective with respect to technologies because their financial possibilities were less than before, engineers had to deal not only with the technicalities of their designs, but also with various social actors and their opinions about what the products should be and do and should not be and not do. Since then engineers and the companies in which they work have learnt to deal with a variety of technical and non-technical (social, human, economic, etc) factors that influence the design work. Designers have to take into account the many-sidedness of reality. So treating ethical problems as design problems means: taking into account the full complexity of the situation. That is the analytical part of design. As far as the synthetic aspect is concerned, it means that ethical problems require creativity and inventiveness in order to be dealt with properly. People involved in ethical issues in engineering can benefit from this insight perhaps even stronger than in other areas, because design is part-and-parcel of what happens in engineering. For them the idea of treating ethical problems as design problems allows them to use their skills and expertise in designing that they had developed anyway for their engineering work.

4. *Ethical values in technology*

Ethical issues emerge in technology because technology involves values. Before examining how the concept of design can be applied to ethical issues in technology, it is good to see how values play a role in technology. This is necessary, because sometimes it seems that values are only involved in our motivation for doing technology. Certainly that is the case. Values determine whether we do technology for the sake of gaining power and control over nature and over humans, or whether we do it for the sake of serving God and/or other people. This is what Carl Mitcham in his book *Thinking Through Technology* called the 'technology as volition' approach to conceptualize technology: technology is a matter of human will and human intentions (Mitcham 1994). But there is more. Values are also elements in technological knowledge. Values are part of what Mitcham called 'technology as knowledge' as a way of conceptualizing technology. The philosophical analysis of technological knowledge is still a fairly unexplored area, but first insights already reveal that norm and values are an essential element in technological knowledge. This can be seen in some of the types of technological knowledge that Walther Vincenti, a historian of technology, defined in his book *What Engineers Know and How They Know it*. He considers knowledge of criteria and specifications as a distinct type of engineering knowledge. Criteria and specifications deal with what should be rather than what is, and therefore norms and values play a role in that type of knowledge. But also in what he defines as 'knowledge of design instrumentalities' there is a lot of normativity involved. Those instrumentalities are, for instance, good strategies for approaching a design problem, and 'good' implies normativity no less than criteria do. Another way of analyzing technological knowledge is by identifying three types of knowledge related to technical artifacts: knowledge of their physical nature, knowledge of their functional nature, and

knowledge of the relationship between physical and functional nature. Here a technical artifact is conceptualized in terms of a physical nature (the artifact's size, weight, color, shape, number of parts, etc.) and its functional nature (what it can be used for). Knowledge of the functional nature entails normativity, because it deals with what the artifact ought to enable me to do. For instance, when an engineer says: "I know that this is a hammer" he says that he knows that it ought to enable him or her to hit nails into some piece of wood. And 'ought to' again implies normativity. In a similar way there is normativity in the knowledge of the relationship between physical and functional nature. When an engineer says: "I know that this material is suitable for realizing the desired function", it is the term 'suitable' that indicates normativity. Prima facie these forms of normativity are not of an ethical nature (they seem to be purely functional), but there is more at stake here. When an engineer says "I know that this is a good hammer" (mark the increase in normativity with respect to the previously cited knowledge statement about the screwdriver), the term 'good' might be meant purely functional, but in practice often also has elements that come much closer to ethics (for example, only those screwdrivers are called 'good' that will do not harm to the user, or that is not made of wood from tropical forests).

Hopefully these examples show, that ethical values are not only present in our motives for doing technology, but also in the knowledge that we make use of. That knowledge can be both the knowledge of the designer-engineer and of the user. Both designers and users can have knowledge about functions of artifacts, and of possible relationships between the physical and the functional nature of an artifact.

5. *Aspects of reality in design*

We have now seen that dealing with ethical issues in technology as if they were design problems helps us to avoid various sorts of reductionisms (and as a consequence take into account the full complexity of the situation) and that ethical issues feature both in the motivation for doing technology and in the nature of technological knowledge. Now we will see how the framework of reformational philosophy can help to analyze the complexity that is involved in design situations and how ethical issue can be made explicit in the knowledge that we can have of the artifact-to-be-designed. As Glas (2006) pointed out, a predicament of Christian philosophy in ethics is to provide the conceptual tools to help people connect to the 'good' for their and others' lives. There is good reason to look in the direction of reformational philosophy because this philosophy in particular has elements that are relevant for dealing with complexity in design situations and the consequences this has for ethics in design. We can recognize that by summing up the basic statements in the framework of reformational philosophy.

- a. Reality makes sense. Reality is filled with meaning and purpose. In reformational philosophy God the Creator of reality is identified as

the source of that. Meaning and purpose are very important in design. The very start of the whole design process is a purpose. This is made explicit in the list of requirements that designers develop in the course of the process.

- b. Reality is inherently and irreducibly complex. This too echoes in technology, as we have seen in section 3. A variety of aspects has to be taken into account in the development of new products and processes. More and more engineers have become aware of this.
- c. Reality is not chaos but displays a character of order and regularity. In the various sciences that order is explored for the various aspects of reality. Here again engineers will recognize the relevance of this notion, because it is that regularity that allows them to make predictions about the behavior of their designs.

In technology these ideas can help us to see how reality can be analyzed when designing. I will now describe this analysis, thereby also using some other elements in the framework of reformational philosophy.

Two reductions are made in the designers' analysis of the technological problem. In the first place the various aspects of reality are isolated one by one. Dooyeweerd has identified 15 aspects of reality, all of which in principle are worth to be considered (although later on it may appear that certain aspects are more important than others in a particular situation). This means that a designer will consider the numeric aspect (e.g., what is a suitable number of parts for the device), the spatial aspect (e.g., is there a limit to the size of the artifact, given the context in which it will function), the physical aspect (e.g., how much energy is needed to make it work), the biotic aspect (e.g., how will the artifact interact with living beings), the psychic aspect (e.g., how will people perceive the artifact), the social aspect (e.g., how will the artifact impact social relations), and the juridical aspect (e.g., is it possible to obtain a patent for the artifact as an invention). I will come back to the ethical aspect later on. A second reduction is to envision the artifact-to-be-designed in terms of a system, as interacting parts that processes matter, energy and information. Such a reduction also entails the analysis of the system layers: for instance, the layers of the socio-technical system as a whole (i.e., the device or apparatus and the social context in which it functions), the technical system, and the components of the technical system. Aspect and system reduction are used to simplify reality in order to get a more precise and detailed view of the problem.

Another step in the analysis is to identify a number of functions for the artifact. In reformational philosophy a number of functions are defined that identify the nature of the artifact. One of those is the founding function. This function indicates in which aspect the existence of the entity is rooted. For a natural object the founding function is in the physical aspect. For a living being it is in the biotic aspect. For an artifact it is in the cultural aspect (or the historical aspect, as it is also called). But as all artifacts have their founding function in the cultural aspect this does not provide much information to distinguish between one artifact and another. More informative is the qualify-

ing function that tells what the artifact is for. At the level of the socio-technical system, the qualifying function of a railway is in the social aspect. At the level of the technical system it is in the spatial aspect (at this level, it suffices to say that it moves people for A to B). Another distinction can be made by using the concepts of subject and object functions. The train can function as a subject in the kinematical aspect (it can move itself, and not just be moved by other entities), but in the economic aspect it can only function as an object (it can be bought, but not buy). One way of characterizing the artifact is by describing the highest aspect in which it functions as a subject. For a train that is in the physical aspect. For a tomato that is in the biotic aspect. These functions can help the designer to get a deeper insight into the nature of the artifact, and also to set priorities in his or her considerations of the complexity of the design situation. When designing a banknote, for instance, the fact that this artifact has its qualifying function in the economic aspect, and not in the aesthetic aspect, means that it is more relevant to make sure that the design is such that the value of the banknote is well recognized than to create a masterpiece of art but with a barely recognizable value. Besides the use of these functions, the regularities or 'laws' in the various aspects help the designer to gain some control over this complexity. The regularities in the physical aspect (studies in the discipline of physics) help the mechanical engineer to design machines and their moving parts. In reformational philosophy descriptive and prescriptive laws are distinguished, both of which are relevant to the designer.

6. *Synthesis in design*

Traditionally there are three basic approaches in ethics: virtue ethics, deontic ethics and consequentialist ethics. All three are related to purpose, aspects and laws in reality (as described in the previous section), but in different ways. In the virtue ethics approach one considers how a human should act in order to reach the goal of his being a human (at least, that is the original Aristotelian teleological version of virtue ethics; according to him virtues are in the nature of humans). This approach focuses on the purpose in reality. The deontic approach seeks men-made and universally applicable laws that hold for everyone in any situation (at least, that is the original Kantian version). It seeks the prescriptive laws in reality. The consequentialist approach looks to the future and considers how to act in order to reach a situation of the best consequences of our decision. In order to investigate the possible effects of our acts, this approach — either implicitly or explicitly — uses descriptive laws in reality. The outcomes of the predictions are then assessed against certain purposes or values. In hedonism, for instance, lust is the primary purpose or value. All three approaches can be found in the practice of ethics in technology. Virtue ethics can be found in those examples where engineers are expected to be loyal to their company, or to be concerned about the safety of the people using their products. The deontic approach can be found in many of the professional ethical codes that can be found in industrial companies. There we find 'laws' such as: never spy, never bribe or accept bribery money. The

consequentialist approach can be found in most of the technology assessment practices, whereby various sorts of possible consequences of innovations are examined and then judged against criteria.

This suggests that if a design approach for dealing with ethical issues is chosen, in principle all of the classical approaches to ethics can be involved in some way or other, depending on the ethical stance one takes. It is also possible that a combination of these approaches will be used. Design is a very integrative activity. It brings together not only the knowledge related to the various aspects of reality and their descriptive and prescriptive laws, but also a variety of methods and approaches. In that sense engineers often act in a very eclectic manner. They pick and choose. This does not mean that they are relativists. They do have a purpose in mind, but in order to reach it they are not very preoccupied with respect to the methods and approaches that can lead to the goal. This made John Dewey as a pragmatist feel quite attracted to engineering because according to him, engineers are pragmatists almost by definition. This, however, certainly does no justice to engineering. Engineers may be flexible in their use of methods and approaches, but still they can be very consistent in believing in lasting purposes and values.

So designing is a matter of both analysis of aspects of realities and their laws) and synthesis (of the different type of knowledge related to these aspects). In the early days of design methodology, the discipline in which the way designers work is studied systematically, it was suggested that analysis and synthesis are sequential: first designers make their analysis (and this leads to a list of requirements, which then is 'frozen'), and then synthesize, i.e., put together, solutions that match the requirements. Empirical research has shown that this is a too simplified story. In reality, designers constantly switch between analysis and synthesis. As they learn more about possible solutions, they learn more about the problem and vice versa. This, too, should be taken into account when ethical issues are approached in a 'designerly' way.

In order to appreciate the role of ethical considerations in technology, one more element in reformational philosophy has to be mentioned. This is Herman Dooyeweerd's idea that each of the aspects has a meaning for all other aspects (via anticipations and retrocipations; this is what he called the universality of the aspects; see Dooyeweerd 1969), and that the laws are specific for each aspect (this is what he called the sovereignty of the aspects). For ethics in technology this means two things.

- The ethical aspect is only one of the aspects that have to be taken into account by designers. They have to find solutions to design problems that do justice to the ethical, but also to the other aspects of reality. This often forces them to seek trade-offs. This is a consequence of the fact that our world is imperfect.
- Ethical issues feature in considerations about all other aspects too. For instance when a designer considers possibilities for obtaining a patent (which is an element in the juridical aspect) for his or her design, ethical issues should be raised (this is evident today in cases of

patents on genetically engineered structures). Glas quoted Troost's remark that if ethics would restrict itself to be the 'science of the ethical aspect' it would become an inert and ineffective party in the moral debate (Glas 2006)

This again illustrates the synthetic character of design: ethical issues have to be combined with issues related to other aspects of reality, and considerations in each of the aspects have an ethical dimension.

What I have argued in this article is that ethical problems can and should be treated as design problems. That approach does more justice to the complexity of reality. This applies also to ethical problems in technology. In that case there is a double design challenge. There is design in the dealing with the ethical issue, and also in the engineering activity itself. The design approach to ethics in technology fits well with a Christian ethics of technology in which the creative gifts of humans as responsible beings should be valued highly.

One could question of course whether this whole account is perhaps artificial and theoretical, and not very much related to practice. In order to show how real this complexity can be, I want to illustrate the account by describing ethical considerations in a relatively new technological area, namely nanotechnology.

7. *Ethics and the complexity of nanotechnology*

Nanotechnology is a fairly undefined term. It is sometimes used as a new term for existing technologies, and sometimes as a term that indicates a type of technology that has not yet resulted in any commercial product. Literally taken, it means technology at the level of nanometers. A nanometer is one millionth of a millimeter and this is about the size of atoms. Nanotechnology therefore is often taken to be the manipulation of individual atoms and molecules to build structures (e.g. very thin layers) and devices. Examples of thin layers are coatings on sunglasses, and this is an example of a nanotechnology that has already become industrial practice. Many applications are still in a laboratory phase, such as medicines that are able to find their way to the right organ in the body and electronics at nanolevel.

The most extreme and futuristic views on nanotechnology are those in which it is expected that we will be able to build self-replicating robots at nanoscale ('nanobots') and other extremely small devices such as miniature cameras (Drexler 1986). Nanotechnology at the moment is very 'hot' and lots of money are put into it (for example in the USA and in the EU). At the same time it gives rise to concern about possible negative effects that can be very dangerous because we are dealing with extremely small entities that can not be seen and therefore can do a lot of invisible damage before being detected. An example of such concerns is the novel *Prey* by Michel Crichton, in which he describes what might happen when a self-reproducing cloud of nanoparticles escapes from a laboratory (Crichton 2002). The most extreme concern is the 'grey goo' in which nanoparticles overtake the whole world and destroy all life as we know

it now. Not only novelists express their concern, though. Maybe nanotechnology is one of the first examples in which the ethics does not come after the technology has already been introduced in society. The effort people now make is to let ethical considerations precede the important decisions about the technology. Therefore the question is: how can a decent agenda for that ethical debate be prepared? Here the considerations presented in the previous sections can play a useful part. I will follow the framework of fifteen aspects, as developed by Dooyeweerd in his *New Critique* and apply them to the existence of nanoartifacts (either existing or in design; see also De Vries 2005).

The numerical aspect focuses our attention on the fact that building a nanoartifact requires an enormous number of atoms and molecules to be manipulated. Drexler has come up with the idea of general assemblers (a sort of artificial enzyme) that will be replicated constantly and meanwhile do the building of nanoartifacts. In such a two-step process the speed of building would increase exponentially and hence make the production of nanoartifacts feasible in time. It can be questioned, however, whether the self replicating process might run out of hand, creating enormous amounts of uncontrolled particles. That question is not only technical, but also moral: are we allowed to take the risk that the amount of nanoparticles runs out of hand (with unpredictable effects)?

The spatial aspect asks our attention for the extremely small dimensions of nanoartifacts. This aspect is in fact what gave nanotechnology its name. That too raises questions that are not only technical, but also moral. Is it, for instance, morally correct when we would be able to create extremely small cameras or devices that can enter the body without us noticing it?

The kinematical and physical aspects require special attention here, as nanoparticles (atoms, molecules) do not behave according to the well-understood classical mechanics, but have quantum behavior. The fact that most of what is called nanotechnology perhaps could better be called nanoscience because it aims at understanding rather than producing has to do with the fact that a better understanding of this behavior is needed in order to be able to manipulate these particles. Here the moral question can be raised whether it is allowed to do this manipulation while we still do not fully understand what we are doing here.

The next aspect in Dooyeweerd's framework is the biotic aspect. Here the question is what nanoartifacts will do to the existing life forms. Here too there is a clear moral dimension to such a question: is it morally correct to develop nanoartifacts as long as we do not yet know what the effect will be on life?

The psychic aspect has to do with our perception of reality. Philosophically there is the interesting issue of the very indirect way in which we have to perceive nanoartifacts and nanoparticles. Heidegger and Borgmann are examples of philosophers who expressed concerns about the way technology, and artifacts (devices in Borgmann's terms) influence our perception of reality. If Drexler's prophecies would become true, nanoartifacts would be everywhere and the effect of artifacts on our perception of reality would be enhanced

strongly. That raises the moral question of whether that is what we ought to strive for.

The analytical aspect also raises a moral question. This aspect points out that we are able to discern between 'yes' and 'no', between 'good' and 'bad', etcetera. Nanoartifacts seem to blur some of the fundamental distinctions that we make. For instance, some people predict that we will be able to build tissue by manipulating individual atoms and molecules. That means that the boundary between living and non-living would become problematic, assuming that it is not well possible to indicate the exact moment at which the addition of one more atom or molecule suddenly makes the artifact cross the border between non-living and living. According to the Dutch philosopher Martijntje Smits, our fear for new technologies often has to do with the fact that we can not use our normal categorizations to define the new technology (Smits 2002). That would then also be the case for nanoartifacts. But is her proposal to solve that problem by just redefining the categories a real solution? Or is it morally preferable to accept the fact that the categorization at stake is based on a difference in reality and not just in our artificial analytical framework, and that therefore denying the difference between living and non-living may be 'punished' by reality?

The next aspect has already been given many names: the historical aspect, the cultural aspect, or the developmental aspect. It is the aspect in which technology finds its roots, as Van Riessen has pointed out (Van Riessen 1949). It is the aspect that is related to the fact that we can have a certain degree of control over our environment and we use that by bringing about new things. The moral question in this context is: is it a good thing when we put the enormous power of being able to manipulate the most fundamental building blocks of matter to become nanoartifacts in human hands? That question becomes even more pressing when we acknowledge the role of evil and sin in the human heart.

The next aspect is the symbolic or lingual aspect. In the context of nanotechnology it draws our attention to the use of rhetoric to promote nanotechnology. Drexler again can be mentioned here. He uses all his linguistic skills to sketch a nanoartifacts-based future that every sensible human should wish to be realized. But how about the morality of that rhetoric? Is it morally correct to use rhetoric for such a purpose given all the uncertainties that nanotechnology still faces? It makes it very difficult to distinguish between what is realistic and what is mere fantasy.

Then there is the social aspect. This aspect brings about the moral issue of a possible new social divide because of nanotechnologies. Who will have access to nanoartifacts and who will not have that? That will be an important question for social justice in a nanosociety (Roco and Bainbridge 2002).

The economic aspect too has a moral dimension. Companies now face the question whether or not to invest in nanotechnology. Governments already are investing lots of money into this, even though the outcomes are still fairly uncertain. Is it morally a good thing to invest in such an uncertain technology

while there are so many pressing problems of hunger and thirst in our world that also demand lots of money?

The aesthetic aspect focuses on harmony as a contribution to the sense reality makes. From a moral point of view one would like to see harmony between technology and nature, and between traditional technologies and nanotechnology. Whether or not this harmony will be there once nanotechnology is fully implemented, however, is uncertain. That is another moral concern in our growing list.

The juridical aspect mostly comes in a late stage in technological developments. In many cases new legislation only comes after the technology has been implemented already, and one can only hope that the worst effects can be limited by his legislation. In nanotechnology, that seems to be not the case. Already now, people are asking how the development of nanotechnology ought to be accompanied by legislation. But Collingridge's control dilemma immediately complicates that desire: at an early stage of development one can have a great influence on those developments but decisions are based on shallow information. Only after developments have progressed substantially it becomes clear what would have been wise. This issue too has a moral dimension to it.

Then there is the ethical aspect, which in Dooyeweerd's framework is primarily concerned with love and care. Here the important (moral) question is whether or not nanotechnology will be serving those purposes, or will be another means for gaining power and control for their own sake.

Finally there is the pistic aspect that makes us reflect on what we believe in and what we put trust in. In many technological developments we see very strong beliefs and trusts in technology. That is certainly the case for nanotechnology too. The large amounts of money that are put into technology nowadays show that. One can ask the moral question of whether it is good to have such strong beliefs and trusts in this technology.

Some of the questions raised above also feature in recent nanotechnology literature. They all deal with possible dangers of this new technology. It should be emphasized, though, that an equal variety of questions can be raised in a positive sense: what are the possibilities that reflection on the various aspects can trigger with respect to the use of nanotechnology as a means to serve purposes in the Kingdom of God? In a Christian ethics of technology such questions most certainly deserve to be studied also.

It is clear that the above is just a sketchy and superficial survey of the moral issues that are related to nanotechnology. It was only written to show that the framework in terms of aspects, as used in reformational philosophy, results in a very broad range of relevant moral questions and issues. It helps us to get an understanding of the complexity of nanotechnology from a moral point of view. It shows the challenge to design solutions that do justice to all these questions and issues. Dealing with moral issues related to nanotechnology can be more than just choosing between alternatives in a moral dilemma, as Whitbeck has argued. In order to do that one would have to investigate the various descriptive and prescriptive laws in the aspects that apply to nanoartifacts and in the design of those artifacts seek for opportunities to reconcile possible

design conflicts in a creative manner. Such a design approach in my view deserves support from those who want to work from a Christian point of view. Reformational philosophy can be a useful analytical instrument to work that out.

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