Understanding Engineering Design and Its Social, Political, and Moral Dimensions

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Abstract

This chapter covers two central issues in the philosophy of engineering design. The first concerns the nature, structure, and function of engineering design. Building on the existing literature, the chapter provides an account of engineering design from a bird's eye view, asking what kind of practice it is, how it relates to other human practices (including other forms of design and other forms of engineering), and how engineering design processes are typically structured. The second issue concerns the moral, social and political choices embedded in design. The chapter investigates what a good design is from the perspective of ethics and society, how new designs can affect society in positive and negative ways, and how design processes can be supportive of values and ideals of a good society.

Keywords: engineering design, design methodology, innovation, design for values, value-sensitive design, social design

Introduction

The philosophy of (engineering) design has emerged in recent decades as a focal area in the philosophy of technology (Vermaas and Vial 2018; Parsons 2015). On the one hand, it has attracted the attention of philosophers after the empirical turn in the philosophy of technology (Kroes and Meijers 2001; Brey 2010a), who hold that a philosophical understanding of engineering design is vital for a philosophical understanding of technology and its consequences for society. On the other hand, many designing engineers are interested in reading about, and contributing to, philosophical discussions of their core practice.

The philosophy of design is concerned with the nature of design, its central concepts, assumptions, theories, and methods; its relation to other human practices; its role in society; and its social, moral, cultural, and political dimensions. In analytic philosophical traditions, there is a focus on understanding and analyzing the concepts, methods, assumptions, practices, and products of engineering design (Vermaas, Kroes, Light, and Moore 2008; Kroes 2012; Meijers 2009; Chakrabarti and Blessing 2014). In continental approaches, the focus is on philosophical-anthropological and social-philosophical analyses of the role and significance of design for humans and society, as well as its aesthetic, cultural, and transcendental dimensions, and there is often a focus on design in general, rather than engineering design alone, with special attention to industrial design, interaction design, architecture, and graphic design (Willis 2018; Bardzell, Bardzell, and Blythe 2018). In both traditions, there have been efforts to address the role of values and politics in design and to investigate ways of introducing ethical, social, and political considerations into design (Van den Hoven, Vermaas, and Van de Poel 2015a; Verbeek 2011).

My main interest is in the moral, social, and political implications of design. How do designs and design processes include implicit moral, social, and political choices that affect society? How can we explicate these choices and amend design processes as a result to make them good designs that are good in an ethical sense and good for society? This will be the main focus of this chapter. However, before we get to a detailed analysis of the relation between engineering design and society, I believe we should first have a proper understanding of engineering design itself, including its nature, structure, and function, its relation to other human practices, and the different types of engineering design that exist. In the next section of this chapter, therefore, I will give an account of engineering design. This account draws from both philosophical studies of engineering design and accounts from within engineering itself. The core of this section is an account of the structure of engineering design processes that will subsequently be used in my account of the moral, social, and political implications of design.

The section that follows focuses on the moral, social, and political implications of design. I will investigate what a good design is from the perspective of ethics and society, how new designs can affect society in positive and negative ways, and how design processes can be supportive of values and ideals of a good society. I will do so in reference to studies of embedded values in design, approaches for the incorporation of values and ethics into design, and theories of the social and political dimensions of design.

2. What Is Engineering Design?

This section will concern the question of what engineering design is and how it is structured. I will begin by answering the question of what type of practice engineering design is, and how it is distinct from other types of design and other human practices. I will then proceed to situate engineering design within the practice of technology development and engineering at large, and will consider its role within, and relation to, innovation. I will conclude by examining the structure of engineering design processes, and how these feed into production and marketing.

2.1 *Engineering Design and Other Forms of Design*

Designing is the creation of a plan for the construction or realization of an object, system, process, or feature. This plan can be of different types: it can be a description of the entity that is to be realized, a series of instructions, a drawing, a graphical model, a series of mathematical equations, or yet something else. Designing is a core activity in a number of professional fields: those fields that are concerned with the planning and production of new things, systems, and processes. Design, in these fields, encompasses the stage during which plans are made for the production of these new things. These fields include the following:

- Engineering, in which one of the central activities is the design of new technological artifacts, systems and processes
- Craft and applied arts (pottery, ceramics, graphics, metal works, textile arts, interior design, etc.)
- Fine arts (painting, sculpture, photography, music, etc.)
- Architecture

Sometimes, “design” is also used in relation to certain branches of the applied social sciences, and then it refers to the planning of new social structures, practices, or events. However, the term “design” is used less frequently in these fields, and instead words like “planning” and “modeling” are more often used. Nevertheless, there are professional activities in the applied social sciences, in which “design” is a central term, like organizational design (the improvement of organization structures and processes to better fit organizational objectives), social design (the design of social structures and processes in order to help solve social problems and promote human welfare),[1] and communication design (the planning and shaping of messages in content, form, and delivery channels).

The word “design” is also used for planning activities by professionals who are not necessarily applied social scientists but who nevertheless make plans for new activities, events, social structures, forms, or organizations, as when a teacher is said to design a new curriculum, or when an administrator designs a new form. And finally, the word “design” is also used in reference to everyday activities of planning, as when it is claimed that a person has designed a plan for making new friends, a cozy reading corner in their home, or a system for distributing and tracking household chores.

Design is therefore an activity that is much more encompassing than engineering design alone. It is a core human activity even in societies that are not technologically advanced. We are *homo faber*, beings that make things, and part of our success as a species is that we use our intellect to develop plans for new tools, artifacts, practices, social arrangements, and other new things that we consider to be useful or meaningful. The activity of making plans or blueprints for such new things is called *designing*, and the plans themselves are *designs*. Designs are usually inscribed in an external medium that people can use as a model or set of instructions for realizing the design. This external medium can be a document, a picture, a physical model, or some other type or representation or series of instructions. Designs can also be internalized, in the mind, as when someone has devised a plan for a new artifact but has not yet put it on paper. Designs can sometimes also be read from things produced that are based on them. When someone has knitted a sweater with an interesting new pattern, for example, people need not see a separate plan for the sweater to understand the new design, as it is in plain view for them.

Engineering design can be distinguished from other types of design by considering the special nature of the activities that it involves. The American Accreditation Board for Engineering and Technology (ABET) defines engineering design as "the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic science and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective" (ABET 2018). ABET moreover defines engineering as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind" (ABET 2018).

These definitions also underline what scholars in technology studies have claimed about engineering design: that it is a form of design that relies on specialist training in engineering science, which includes extensive knowledge of the mathematical and natural sciences, and the methods of applying such knowledge. The intense application of mathematics and natural sciences is certainly something that sets engineering design apart from other forms of design. However, as many scholars have argued, engineering is not merely the application of science and mathematics; it also involves the creation and application of unique engineering knowledge, which is a highly formalized, evidence-based, and systematic type of knowledge (Vincenti 1990). Based on these studies, a more adequate definition of engineering design than the ABET definition would state that design involves the application of science, mathematics, and engineering knowledge. So let us reformulate the definition of engineering design: Engineering design is the development, through the application of science, mathematics, and engineering knowledge, of plans for products (devices, systems, methods, procedures) that can serve practical ends.

Engineering design is not only distinct in its practices, but also in its resulting plans. As Clive Dym (1994) has argued, engineering design uses special "languages of design," that is, particular symbol systems, notations, systems of icons, and graphical conventions for drawing up and communicating design plans, that are altogether different from those used in other fields. These languages are used to represent objects and processes. As Dym claims, designers use a physical representation language based on mathematics, science, and engineering knowledge to produce mathematical and analytical models to express some aspect of an artifact's function or behavior. Designers also use graphical representations of various kinds, often involving exact measurements and representational conventions from the engineering sciences, and often interpreted within CADD systems. In addition, designers use verbal or textual statements to document and communicate designs and describe objects, constraints, and limitations with concepts and terms unique to the engineering sciences and symbolic representations derived from symbolic computing and AI-based programming, such as if–then rules, frames, and computationally defined objects.

Engineering design is also distinct in the products and processes that are realized on the basis of designs, which have unique characteristics not found in the products of other types of design. To demonstrate how this is so, I will consider the four main branches of engineering and the designs that they typically yield. The four main branches of engineering are chemical engineering, civil engineering, electrical engineering, and mechanical engineering. They are involved in the design and manufacture of artifacts that typically cannot be produced outside of engineering.

Chemical engineering is involved with the production, transformation, and utilization of chemicals, materials, and energy through the application of principles of chemistry, physics, and mathematics. Chemical engineering enables the production of artifacts such as medicine, petrochemicals, and plastics, and the development of processes such as oil refinery and mineral processing, all of which could not exist if it were not for chemical engineering design.

Mechanical engineering is concerned with the design, analysis, manufacture, and maintenance of mechanical systems. It applies physics, mathematics, materials science, and engineering knowledge to do so. It may be observed that mechanical systems like steam engines, windmills, and water wheels were already developed and used thousands of years ago, before the development of the engineering sciences as we currently know them. Although such relatively simple mechanical systems can be developed outside of mechanical engineering, it is only the application of sophisticated science, mathematics, and engineering knowledge in mechanical engineering that has enabled the production of more advanced mechanical systems such as engines, automobiles, industrial machines and robots, and the optimization of simpler systems like windmills and steam engines.

Electrical engineering is concerned with electrical, electronic, and electromagnetic systems—such as televisions, telephones, radar systems. and the electric grid—that clearly could not be manufactured if it were not for electrical engineering and its extensive reliance on mathematics and natural science.

Civil engineering is concerned with the design, construction, and maintenance of the built environment, including structures such as roads, bridges, canals, dams, sewerage systems, and railways. Many of these structures were already being designed and built by artisans thousands of years ago. The emergence of a scientific approach in civil engineering, however, has led to dramatic advances in the kinds of structures that can be built and the functionality that they have.

Computer science and computer engineering are more recent fields that do not neatly fit within this engineering taxonomy. Computer science is normally considered to be a branch of science rather than engineering. It is the study of computing devices and the way in which they process, store, and communicate data and instructions. This is often done toward a practical end, however, which is to improve the processing of data and instructions in computing devices. Because of this practical aim, computer science has a resemblance to engineering, even if it is considered a science. Computer engineering is different from computer science. It is the combination of computer science and electrical engineering. It is generally considered to be a branch of electrical engineering. Computer engineers design computer hardware and software, as well as systems that integrate both.

2.2 *Situating Engineering Design in Engineering and Innovation*

Engineering design is a central practice in engineering. Yet, it is not the only practice. Engineers are also involved in research activities prior to design and in activities that take place after design, notably the manufacturing, operation, and maintenance of technological artifacts and systems. Research in the engineering sciences is distinct from research in the natural sciences in that it is, to a greater or lesser extent, application-oriented (Boon 2011). It follows scientific methods, including scientific methods of experimentation, observation, hypothesis testing, and establishment of law-like relationships, but its aim is not to uncover perennial truths about the universe, but rather to create useful knowledge that may have a future application in engineering design. Examples of such research include the investigation of properties of different types of alloys in materials science and the study of the impact of liquid droplets on superheated surfaces. Sometimes the term *engineering scientist* is used to designate engineers who engage in this type of applied research.

Engineers also have roles in production and manufacturing. Notably, such roles are taken up by production engineers. Production engineers are involved in the design of equipment, tools, and machinery used in manufacturing processes, as well as in the implementation, monitoring, and optimization of manufacturing and production processes. They work together with many other professionals in the production and manufacturing process who often do not have engineering degrees, such as assemblers, machinists, welders, production managers, and quality control inspectors. Engineers can have roles in maintenance, as well. Maintenance engineers are involved in the checking, repairing, and servicing of machinery, equipment, systems, and infrastructures. As these cases show, there are many engineering professions and jobs in which engineering design is not central. However, engineering design, being the activity aimed at inventing, defining, and planning the technological artifacts and processes, is clearly a salient and central component of engineering.

As engineering design is central in engineering, it is also central in technological innovation. *Technological innovation* is the invention of new concepts, techniques, and designs in engineering that are then realized into products and subsequently marketed and included in social and economic practice. Technological innovation is more than mere *invention*, which is merely the development of new ideas, concepts and designs (Malerba and Orsenigo

1997). It goes beyond invention by requiring implementation: it also involves subsequent product realization, marketing, and diffusion into society. Although technological innovation often depends on innovative designs, it can also be the result of the invention of new concepts and techniques at research and pre-design stages, and can also involve innovative production and marketing processes.

Technological innovation is only one type of innovation. 'Innovation' can be defined as activities by an organization or unit to produce innovations, and an innovation is "a new or significantly improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD/Eurostat 2018, 20). An innovation can be a technological product or process but also a regular good or service; a new marketing method or commercial practice; a new policy; or a new organizational method, form, or practice. Innovation can be undertaken by commercial firms but also by governments, NGOs, and other organizations and groups. Innovation undertaken to better meet social needs is called *social innovation*. As seen in the definition of innovation provided, a distinction is often made between 'product innovation' (the introduction of goods or services that have new or improved characteristics or uses) and 'process innovation' (the implementation of new or improved production or delivery methods). This distinction also applies to technological innovation.

It should be observed that not all technological design is necessarily innovative. Much technological design is routine design. 'Routine design' is defined by Gero (1990, 32) as "design that proceeds within a well-defined state space of potential designs. That is, all the variables and their applicable ranges, as well as the knowledge to compute their values, are all directly instantiable from existing design prototypes." Routine design does not involve much innovation and creativity. At the other extreme, one finds 'innovative' and 'creative design,' which involve substantially new design plans or solution principles, and in between are various forms of 'redesign,' including variant and adaptive design, in which an existing design is improved upon by finding ways to satisfy new requirements or improve performance (Pahl and Beitz 1996).

2.3 *Structure of the Engineering Design Process*

In theoretical and methodological studies of design, in engineering design textbooks, and to a lesser extent in the philosophy of design, considerable attention is paid to the structure of the design process. In accounts of this structure, various steps or phases of design practice are distinguished and related to each other, often with elaborate diagrams to illustrate the different steps. Most authors distinguish four to eight stages in design, which often can be iteratively applied, starting from formulation of the problem or need and formulation of design requirement, to conceptual design, in which basic ideas are formed for the solution to the problem, including the broad outlines of function and form, to detailed design, in which detailed plans, specifications and cost estimates are made, and in which final instructions are made for production (Johanneson and Perjons 2014; Jack 2013; Chakrabarti and Blessing 2014).

I focus here on the account of design processes provided in a prominent study of engineering design by Pahl, Beitz, Feldhusen, and Grote (2007). Pahl et al. describe the design process as having five phases:

1. *Product planning* is the development of an idea for a new product that results in a task description for an engineering department for development of the new product. Product planning is often not done by designers themselves but by clients and product planning departments or marketing departments of companies. It is often based on a real or perceived need expressed by a client or thought to be located in the market.
2. *Task clarification* is the process of clarifying the kind of product that is needed, identifying and formulating requirements and constraints, and creating a list of requirements, or design specification. Product planning and task clarification are often integrated processes in which there is input back and forth between planning and clarification.
3. *Conceptual design* is the process of finding a solutions to any problems posed by the design specification at a conceptual level. Conceptual design involves identifying essential problems through abstraction, establishing function structures in which overall functions are divided into subfunctions, searching for appropriate

working principles to drive the subfunctions, and combining them into working structures. The result is called a design concept or principle solution.

4. *Embodiment design* is a phase in which a design concept is developed into a definitive layout of the proposed technical product or system. This involves developing a layout design that defines the general arrangement and spatial features of the product, a preliminary form design that stipulates component shapes and materials and production processes, as well as providing solutions for any auxiliary functions not covered in the conceptual design stage. It strongly involves technical and economic considerations, and must result in a design that can be checked for its function, durability, production and assembly, operation, and cost. Embodiment design often involves several repeat design processes before a definitive design emerges.
5. *Detail design* is a phase that completes the embodiment design process with final instructions before production. These final instructions concern shapes, forms, dimensions, and surface properties of components; a definitive selection of materials; a final specification of production methods, operating procedures, and costs; and the development of production documents that include component and assembly drawings and parts lists. This is still done by design departments rather than production departments. Detail design may also involve the development of assembly instructions, transportation documentation, and quality control measures for the production department and operating, maintenance, as well as repair manuals for users.

Pahl et al. emphasize that engineering design is an iterative process: at any phase in the design processes, designers may retreat to an earlier phase, and it is also possible that different engineering teams work on different phases simultaneously.

After the detail design phase, the production department takes over from the engineering department and manufactures the product. In practice, detail design and production often overlap and thus require close collaboration between design and production departments. After production, there is transfer to the client and/or installation (for unique products) or marketing (for mass-produced products). For mass-produced products, user and marketing analytics, which is increasingly based on big data analytics, will often be collected after distribution and consumption, which could then lead to changes in the design for new batches of the product (Eppinger and Geracie 2013; Xu, Frankwick, and Ramirez 2016).

A potential weakness of the Pahl et al. account is that it makes little reference to prototyping and testing, processes that are often used in engineering design. 'Prototyping' is the production of inexpensive, scaled-down versions of a product or specific features of it, so that problem solutions generated at an earlier stage can be investigated. Pahl et al. do cover its role in design, but only briefly. They claim that prototyping can occur at any stage in the design process and that it frequently is used at the conceptual stage to test fundamental design concepts, but also at later stages in the design process (Pahl et al, 2007, 133). *Testing* is the assessment of the performance, safety, quality, or compliance with standards of a designed product or system, subsystem, or component. Testing can be done through prototyping, but is often done with a fully realized product, subsystem, or component. Consumer testing is a special form of testing, in which the product is tested with prospective consumers to see if it meets their expectations. Testing often takes place during production, after which results can feed back into design if the test results give indication that a redesign is needed. It also takes place during the design process, however, where it can occur during almost any stage, but especially during the later stages. It seems to be a weakness of the Pahl et al. account that it makes very little reference to testing.

3. Good Design and the Ethics of Design

In this section, I investigate to what extent and how moral, social, and political choices are embedded in design and how they can be designed for. I start by investigating what it means to say that a design is good, and I examine the relation between engineering design, on the one hand, and values, benefits, and the good of society, on the other hand. Then, in section 3.2, I investigate how consequences for society can be embedded in design, and in section 3.3, I conduct a parallel investigation of the embedding of values in design. Finally, in section 3.4, I consider approaches to designing for values and benefits to society.

3.1 *What Is a Good Design?*

A good design is a design that results in a good technological product. So what, then, is a good technological product? One answer is that it is a product that fulfills its function well. On this conception, a good microwave oven is one that is good at microwaving food, and a good radar system is one that is good at detecting moving and stationary objects. Let us call this type of goodness 'functional goodness.'[2]

A second answer is that a good technological product is one that is good at meeting the design requirements that have been specified for it. For example, the design requirements for a wrist watch may include requirements such as ability to tell the time (its proper function), being made out of metal parts, being of certain dimensions so as to be wearable, being made of nontoxic materials, being original in its design, being cost-effective to make, being easy to read, not having sharp edges, and being able to be mass-produced. Let us call this type of goodness 'requirements goodness.' Note that requirements goodness normally includes functional goodness: among the requirements for a new technological design are usually requirements that one or more functions are performed well by the product in question.

A technological product may be good in the requirements or functional sense, but still be bad in other ways. For example, a product may be bad for one's health or bad for the environment despite having functional and requirements goodness. This can happen when its original requirements do not include those of it not being harmful to health or to the environment. This type of goodness, when something is not good or bad *at* something (such as performing a function or meeting requirements), but good or bad *for* something, is called 'prudential goodness' (Fletcher, 2012). It is a relation between an entity *E* and an entity *F* for which or whom *E* is good.[3] To say that *E* is good for *F* is to say that *E* contributes to the existence, flourishing, welfare or excellence of *F*. *F* can be anything that is of positive (intrinsic or instrumental) value. In particular, it can denote persons, positive or desired conditions, qualities or capabilities of persons (e.g., health, [low] blood pressure, endurance), groups (e.g., children, disabled individuals), practices and institutions (e.g., the economy, family life), social conditions and values (e.g., social cohesion, civility, privacy), as well as the environment and society at large.

The types of prudential goodness that have traditionally been considered to be the most important are goodness for persons and goodness for society. Other types of prudential goodness are arguably subordinate or contributory to these two more fundamental types. For example, goodness for health is contributory to, and subordinate to, goodness for persons, since that things going well for us in general is more important to us than things going well with our health, since this does not prohibit other things for us going badly. Likewise, goodness for the economy is contributory to, and subordinate to, goodness for society.

In Brey (2018) I argue that the goodness of society is more important than goodness for persons, since the well-being of persons should be seen as a component of any conception of a good society. I moreover argue that next to well-being, justice is an intrinsically valuable good in society, and that other dimensions of a good society, like democracy, freedom, sustainability, and community, are best analyzed as instrumentally valuable to well-being and justice. There are, however, different conceptions of a good society, in which for example sustainability or ecological integrity is seen as intrinsically valuable, or in which democracy, autonomy, or individual rights are seen as intrinsically valuable. On many theories of goodness, however, goodness for society, however it is conceived, is the most important or highest form of goodness, and therefore the highest form of goodness for a technological product is its goodness for society. This means that a prudentially good design, in the most general sense, is one that results in products that tend to be good for society.

Prudential goodness (for society, human beings, or something else) is not the same as moral goodness, and in philosophy, the two have usually been distinguished. Moral goodness relates to right and wrong. Someone else’s money can be prudentially good for me, but it can be morally wrong for me to accept it if it is not freely given. Prudential and moral goodness can, however, be related in the following way. Moral values are among those things that can be benefited or harmed, as when one says that actions harm privacy or support justice. So entities can be prudentially good or bad for moral values. A technological product can therefore be said to be morally good if it is prudentially good for moral values. A technological product is morally good for moral value *V* if it tends to support *V* rather than violate it. For example, Internet software that tends to divulge one's personal information to third parties is morally bad with respect to privacy, and software that tends to support the protection of personal information is morally good with respect to privacy. When a technological product tends to support all key moral values, we can say that it is morally good in a general sense.

Moral goodness is, in my view, contributory to the goodness of society. That is, a society in which people behave morally, institutions are arranged in accordance with moral principles, and technological products tend to be supportive of moral values is a better society than one in which this is not the case. It should also be clear, however, that moral goodness is not constitutive of the overall goodness of society. That is, there is more to being a good society than it being a moral society. A society can be moral, but still fall short because it has a poor economy, poor institutional arrangements, poor management of hazards and risks, and other shortcomings that keep it from being a good society. In the view I am proposing, one of the ways in which technological products can contribute, or fail to contribute, to the goodness of society is through their upholding, or violation, of moral values, and when a technological product upholds a moral value one could say that it is prudentially good for that value, and thereby, at least with respect to its support of morality, that it is prudentially good for society.

In conclusion, we have learned that a design (of a technological product) can be called good in at least four senses: it can be functionally good, have requirements goodness, be prudentially good, and be morally good. The last type can, however, be subsumed as a special kind of prudential goodness. The most important form of prudential goodness that can be considered in design is goodness for society, as it arguably encompasses other forms of prudential goodness, including goodness for moral values (moral goodness). I have argued that goodness for society appears to be a more important form of goodness for technological products than functional or requirements goodness. I now turn to the question of whether and how both goodness for society and moral goodness can be considered in design. I do so by examining how designs may affect society and how designs may affect the realization of moral and non-moral values, after which I will consider how these influences may be accounted for in design.

3.2 Technological Products with Built-in Consequences

The question is then whether we can come up with a viable theory of technological design according to which designs can yield products that are in a systematic and predictable way contributory to the goodness of society and its constituent parts. A possible argument against the existence of a viable theory of this sort is that that it is the use of an artifact that determines its effects, not the design. I have called this the *neutrality thesis* (Brey, 2010b): the thesis there are no consequences that are inherent to technological artifacts, but that artifacts can always be used in a variety of different ways, and that each of these uses comes with its own consequences.[4] The neutrality thesis can be made plausible with examples of simple tools like hammers and razors. A hammer can be used to hammer nails, but also to break objects, to kill someone, to flatten dough, to serve as a paper weight or to conduct electricity. Different uses of a hammer have radically different effects on the world, and there do not seem to be single effects constant in all of them. If the neutrality thesis is true, it would seem to follow that attempts to improve society should perhaps not pay much attention to technological artifacts themselves, because they in themselves do not "do" anything. Rather, they should focus on the usage of these artifacts.

As many have argued, however, the neutrality thesis is false (Rose 2012; Verbeek 2005; Brey 2010b). Cases to buttress the neutrality thesis usually make reference to versatile tools like hammers, which have many very different uses. Most technological products, however, have only a limited range of (sensible) uses, and there are recurrent consequences across many or all of these uses. An ordinary gas-engine automobile, for example, can evidently be used in many different ways: for commuter traffic, for leisure driving, to taxi passengers or cargo, for hit jobs, for auto racing, as a temporary shelter for the rain, or as a barricade. Whereas there is no single consequence that results from all of these uses, there are several consequences that result from a large number of these uses: in all but the last two uses, gasoline is used up, greenhouse gases and other pollutants are being released, noise is being generated, and at least one person (the driver) is being moved around at high speeds.

These uses also have something in common: they are all central uses of automobiles, meaning that they are accepted uses that are frequent in society and that account for the continued production and usage of automobiles. The last two mentioned uses are peripheral in that they are less dominant uses that depend for their continued existence on these central uses, because their central uses account for the continued production and consumption of automobiles. Central uses of automobiles make use of their capacity for driving, and when it is used in this capacity, certain consequences such as the ones mentioned are very likely to occur. What this example suggests is that technological products are not neutral but may be claimed to have cross-cutting, "embedded" or "built-in" consequences or effects. What this means is that particular consequences manifest themselves in all of the *central* uses of the technological product (Brey 2010b). A central use is a use that is prevalent in society, and tends to make use of advanced functional features of the product, that are the result of a complex technological design.

It should be acknowledged that even if a technological product is used according to one of its central uses, there are often ways to avoid particular consequences. For example, a gas-fueled automobile need not emit greenhouse gases into the atmosphere if a greenbox device is attached to it, which captures carbon dioxide and nitrous oxide and converts it into bio-oil. The notion of a built-in consequence does not refer to consequences that are necessary and unavoidable, but rather to strong tendencies. So no strong technological determinism is implied, but only a weak, contextual determinism, which holds that technological products can be associated with recurrent effects that have a tendency to manifest themselves across their central uses, barring exceptional circumstances (Brey 2005). To deny such recurrent effects is to fall back into the neutrality thesis and therefore to miss the opportunity to address these recurrences in the design process. It is simply wrong to say that the emission of greenhouse gases by automobiles is a result of their use and not their design, when there are designs that are associated with such emissions (as in gasoline-fueled cars) but also designs that are not (as in electric cars). In Brey (2006), I present a taxonomy of different kinds of recurrent consequences of technological products, including social, cultural, material, behavioral and other types of consequences.

I have argued previously (Brey 2005) that recurrent effects associated with technological artifacts can be understood as resulting from affordances and constraints associated with an artifact. Affordances are new actions, events or configurations of the environment opened up by artifacts. Constraints are limitations to configurations of the environment imposed by artifacts. Embedded consequences of technological products can moreover often be evaluated as positive or negative. If they are evaluated as positive, they may be called embedded or built-in *benefits*. For example, Bruno Latour's (1990) hotel keys with a weight attached have as a benefit that they tend to be deposited at the front desk. If embedded consequences are negative, they are embedded *harms*. For example, the emission of greenhouse gases is an embedded harm of gas-engine cars.

3.3 *Technological Products with Built-in Values*

We have seen that technological products can be associated with "built-in" consequences, and that these consequences can be beneficial or harmful in relation to persons and other valuable entities. I will now claim that just as technological products can be beneficial or harmful to persons, the economy, or the environment, they can also be beneficial or harmful to *values*. That is, they can be beneficial or harmful to the realization of values in the real world, meaning the extent to which events and states-of-affairs are shaped or brought into effect in accordance with particular values. Freedom, justice, or privacy are abstract qualities, of which there can be more or less in the world. The amount of freedom in the world, for example, depends on the extent to which individuals have freedom of movement, thought, expression, and association. If many individuals do not have this, there is less freedom in the world, and if many have it, there is more. For a technological product to be beneficial to freedom, therefore, it must have a systematic tendency, across different uses, to bring about more freedom in the world.

The claim I want to make, then, is that technological artifacts can have systematic tendencies to promote or benefit values such as privacy and sustainability, as well as tendencies to harm or detract from them. In short, one can associate technological products with values embedded in them. This approach to technology is called the 'embedded values approach' (Nissenbaum, 1998). Observe that, following from the definition of prudential goodness in section 3.1, a technological product that promotes or upholds a value is prudentially good for (the realization of) that value, and one that harms a value is prudentially bad for it. So a product with an embedded value of privacy is (prudentially) good for privacy, and one with an embedded tendency to harm privacy is (prudentially) bad for privacy. The embedded values approach was originally formulated by Helen Nissenbaum (1998, Flanagan, Howe, and Nissenbaum, 2005) and Batya Friedman (Friedman, Kahn, and Borning, 2006). I have also worked on an embedded values approach since the late 1990s (Brey, 2000, 2010b).

An approach related to the embedded values approach, and chronologically preceding is, is the approach of embedded politics in technological products. Langdon Winner (1980) famously asked, "Do artifacts have politics?" and then proceeded to answer this question affirmatively. The politics of artifacts can concern their promotion of particular political arrangements and processes (e.g., hierarchical structures, privatization processes), but also political values and ideals (e.g., distributive justice, democracy, equality). If the latter are at issue, then the embedded politics approach coincides with the embedded values approach. Another related approach is the technomoral virtue ethics approach of Shannon Vallor (2016). Vallor claims that particular technologies tend to promote the development of certain virtues and vices in users: virtues such as honesty and empathy, and vices such as dishonesty and carelessness. This approach can also be understood as a special version of the embedded values approach.

3.4 *Designing for Values, Benefits, and a Good Society*

The idea that technology is not neutral and that values and consequences can, to some extent, be embedded in design, is at the heart of various approaches to design that have been developed in recent decades. I first briefly consider approaches to design that focus on the realization of certain types of benefits, or that focus for benefits for society at large, after which I discuss approaches that focus on the realization of values.

There are many approaches to design that focus on the realization of particular benefits for society. Environmental design is an approach to design that focuses on developing products and structures that are sustainable and beneficial for environment and health. User-centered design is design that tries to better accommodate for the needs, goals, and behavioral tendencies of users. Universal design is the design of product and environments all people, without the need for adaptation or specialized design. Behavioral design (Wendel 2013) and persuasive technology (Fogg 2002) are approaches that aim to change people's behavior, daily routines, and thinking, thereby providing benefits to users and society. Social design (Sachs, Banz, and Krohn 2018) is design aimed at solving social problems, improving welfare, and bringing about social change. In these approaches, the social benefit that is being designed for can either be encoded in the proper function of products (e.g., a weight-loss app that has the function of influencing food intake, a waste-sorting system that has the function of enabling recycling, and hence contributes to sustainability) or be an embedded benefit distinct from the proper function (e.g., an electric car, whose function is transportation, but that also contributes to sustainable practices).[5]

Design approaches based on the concept of embedded values find their beginning in the seminal work of Batya Friedman and her associates (Friedman, Kahn, and Borning 2006; Friedman and Hendry 2019). Friedman developed the approach of 'value-sensitive design,' an approach to account for and incorporate human values in a comprehensive manner throughout the design process. This approach was initially developed for the design of information systems but is more broadly applicable. It proposes investigations into values, designs, contexts of use, and stakeholders with the aim of designing systems that incorporate and balance the values of different stakeholders. The key activities in value-sensitive design are the identification of direct and indirect stakeholders and the benefits and harms for each group that may result from the system that is to be designed (empirical investigations); the mapping of benefits and harms onto corresponding values; conceptual investigations of key values and the identification of potential value conflicts and the proposal of solutions for them (conceptual investigations); and studies of how properties of the to-be-designed artifact may support or counteract human values and the artifact may be designed proactively in order to support specific values that have been found important in the conceptual investigation.

Many scholars have been inspired by the value-sensitive design approach, and while some work within its scope, others have developed alternative approaches for incorporating values into design. The term 'design for values' is sometimes used to denote the broader family of design approaches that incorporates the idea of value embeddedness (Van den Hoven, Vermaas, and Van de Poel 2015b). As I have argued (Brey 2010b), different approaches to design for values hold different positions on how the relevant set of to-be-promoted values should be identified (e.g., through stakeholder consultation, normative ethical analysis, consultation of constitutions and (inter)national declarations on rights and ethics, or combinations thereof); how value conflicts should be resolved (through deliberation by stakeholders, consultation of stakeholders, normative analysis, or other means); and how values can be translated into design requirements.

It is important to realize that design for values approaches are not necessarily constrained to moral values. They are sometimes thought of as such, and there are a few design-for-values approaches that have a more specific focus on morality and ethics. However, most approaches, including value-sensitive design, consider non-moral values as well. Values come in many sorts, and next to moral values, one can find, among others, esthetic, economic, social, cultural, epistemic, spiritual, and personal values. As I argued in section 3.1, moral values are important to society, as they allow one to distinguish right from wrong, but they do not define the totality of what is valuable or good. Therefore, as I argued, a good society is not the same as one in which moral values are realized. However, a broader design for values approach that includes non-moral values as well could be a viable approach for design for a good society, because a good society can, at least to a considerable extent, be defined in terms of a set of values that should be realized for a society to be good. If one is only interested in ethical design, then design for values approaches are also of use; one simply makes the choice to only consider moral values in the value selection process.

A shortcoming of values in design approaches is that they do not include detailed and rigorous design methodologies that specify how conceptual, empirical and technical investigations should proceed and should be integrated with each other (Manders-Huijts 2011). There is often no detailed methodology for identifying and surveying stakeholders, for translating stakeholder benefits and harms to values, for making value trade-offs, for translating values into design requirements, and for integrating design for values approaches with "mainstream" design methodologies. Recent work attempts to address some of these issues within value-sensitive design (Friedman, Hendry, and Borning 2018) and in other approaches (Van de Poel 2015; Kroes and Van de Poel 2015; Vermaas, Hekkert, Manders-Huits, and Tromp 2015).

In the remainder of this section, I will make a modest contribution to this recent development by considering how design for values approaches can be related to the account of design processes by Pahl et al. that was discussed in section 2.3. The most important phase in the Pahl et al. account to incorporate value issues is, I claim, the task specification phase, which comes after the initial product planning phase. In the task specification phase, the kind of product that is needed is clarified, and requirements and constraints are identified and formulated, resulting in a requirement list. Naturally, during this phase, values would be identified and included in the requirement list. For example, at this point it could be specified that the product should protect the privacy of users and other stakeholders, or that it should be supportive of the overall well-being of users. At this phase, recommendations and requirements regarding value trade-offs could also be made. This is not to say that values should not be considered at all during the prior product planning phase. If values are front and center during this phase already, then it is less likely that product ideas will be developed that are incompatible with relevant values, and that later discovery of this fact, if it takes place at all, requires a radical redesign.

During the subsequent conceptual design phase, conceptual-level design solutions are found for the challenge posed at the task clarification stage. For example, the design of an information system would include a conceptual specification of basic functions and subfunctions of the system, and working principles for these subfunctions and their combination into working structures. If one of the design specifications is that the system should be protective of the privacy of the users, then at this phase, design solutions are sought in which no personal information from the user is recorded, such recording is by design temporary, or such recordings are contained so that they are not accessible by third parties. For some values, the level of abstraction of the conceptual design phase may be too high to enable specifying design features that are relevant for their realization, and these values could come into focus later, at the embodiment design or detail design phases. What is needed, and does not exist at this point, is a general methodology for operationalizing and integrating value requirements at the conceptual design phase, including conceptual-level operationalization of particular values.

Next, at the embodiment design phase, the product is defined at a more concrete level, including its general arrangement, spatial features, shape and materials, and auxiliary functions not covered at the conceptual design stage. At this stage, concrete implementations need to be found for the conceptual-level solutions found for the inclusion of values in the conceptual design phase. For example, if during that phase, it was found that personal information input by users should only be stored temporarily, now a specific solution is needed for how this is done, for example by only storing such information in a dedicated of section of RAM and having algorithms in place that prevent it from being stored permanently. Also missing at this point for this stage in the design process are general as well as value-specific methodologies for translating conceptual-level value solutions to embodiment-level solutions.[6] Finally, the embedding of values may also partially take place during the detail design phase, when a definitive determination of shapes, properties, materials, and production methods is made. Because the success of designing for values is to be measured by the success a design has in actually promoting these values when in actual use, testing, including consumer testing (or better: stakeholder testing) could also be an important component of value in design approaches, as would evaluation and possible redesign based on investigations of market response and possibly also social and ethical impact assessments that are performed after introduction to market.

4. Conclusion

In this chapter, I investigated two issues: the nature of engineering design and the moral, social, and political choices embedded in design. Engineering design was related to other types of design and other human practices, and was defined as the development, through the application of science, mathematics, and engineering knowledge, of plans for products (devices, systems, methods, procedures) that can serve practical ends. It was argued, as well, that engineering design is distinguished from other (design) practices by its unique methods, produced knowledge, and manufactured products. Engineering design was also situated among other engineering practices, and was related to technological innovation, in which innovative design often, but not always, plays a significant role. I also considered the structure of the design process, and examined an influential conception of it by Pahl et al. (2007), which distinguishes five phases in design.

I then turned to the ethical, social, and political dimensions of design. I started by distinguishing different meanings of "good design" and analyzing the relation between engineering design, on the one hand, and values, benefits, and the good of society, on the other. I argued that the most important type of goodness of a technological product is its goodness for society, and that other types of goodness (functional goodness, specifications goodness, moral goodness, prudential goodness for aspects of society) are subordinate to it. I then investigated how values and consequences for society can be embedded in design, a theory of which is needed for formulating approaches to design that are beneficial to society and its constituent elements. Finally, I investigated and critiqued approaches for designing for values and benefits for society, and made my own contributions to this debate.

Approaches to design that focus on values and benefits to society have a lot of promise, but methodologies for them need to be developed more and integrated with mainstream design methodologies. If this were to happen, they could eventually become part of the mainstream engineering education. There is certainly a lot of interest in society in the development of technology that is ethical and beneficial to society. It should be considered, though, that these approaches may be best applied by multidisciplinary teams, which include members with training in humanities and social sciences, or engineering teams in which some of the engineers have a multidisciplinary background. The take-up of this kind of approach ultimately depends on the interest of commercial firms in developing technologies in this manner, taking into account that technology development takes place for the most part in the private sector. It will depend on the way firms conceive of and implement corporate social responsibility, and on the legislation and regulations that will be in place to constrain and guide design and manufacture.

References

ABET. 2018. Criteria for Accrediting Engineering Programs, 2018–2019. Accessed at https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/, 6/14/2021..

Bardzell, Jeffrey, Shaowen Bardzell, and Mark Blythe, eds.. 2018. *Critical Theory and Interaction Design*. Cambridge, MA ; London, England: MIT Press.

Boon, M. 2011. "In Defense of Engineering Sciences." *Techné* 15 (1): 49–71.

Brey, Philip. 2000. "Disclosive Computer Ethics: The Exposure and Evaluation of Embedded Normativity in Computer Technology." *Computers and Society*, 30(4): 10–16.

Brey, Philip. 2005. "Artifacts as Social Agents." In *Inside the Politics of Technology. Agency and Normativity in the Co-Production of Technology and Society*, edited by Hans Harbers, 61–84. Amsterdam University Press.

Brey, Philip. 2006. "The Social Agency of Technological Artifacts." In *User Behavior and Technology Development: Shaping Sustainable Relations Between Consumers and Technology*, edited by Peter-Paul Verbeek and Adriaan Slob, 71–80. Dordrecht: Springer Netherlands.

Brey, Philip. 2010a. "Philosophy of Technology after the Empirical Turn." *Techné: Research in Philosophy and Technology* 14(1) 1–13.

Brey, Philip. 2010b. "Values in Technology and Disclosive Computer Ethics." *The Cambridge Handbook of Information and Computer Ethics*, 41–58.

Brey, Philip. 2018. "The Strategic Role of Technology in a Good Society." *Technology in Society* 52: 39–45.

Cavoukian, Ann. 2012. "Privacy by Design: Origins, Meaning, and Prospects for Assuring Privacy and Trust in the Information Era." In *Protection Measures and Technologies in Business Organizations: Aspects and Standards*, edited by George Yee, 170–208. IGI Global.

Chakrabarti, Amaresh, and Lucienne T. M. Blessing, eds. 2014. *An Anthology of Theories and Models of Design: Philosophy, Approaches, and Empirical Explorations*. London: Springer-Verlag.

Dym, Clive. 1994. *Engineering Design: A Synthesis of Views*. New York: Cambridge University Press.

Eppinger, Steven D., and Greg Geracie. 2013. *The Guide to the Product Management and Marketing Body of Knowledge*. Product Management Educational Institute (PMEI).

Flanagan, Mary, Daniel C. Howe, and Helen Nissenbaum. 2005. "Values at Play: Design Tradeoffs in Socially-Oriented Game Design." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 751–760. CHI '05. New York, NY: ACM.

Fletcher, Guy. 2012. "Resisting Buck-Passing Accounts of Prudential Value." *Philosophical Studies* 157 (1): 77–91.

Fogg, B. J. 2002. *Persuasive Technology: Using Computers to Change What We Think and Do*. 1st ed. Amsterdam, Boston: Morgan Kaufmann.

Friedman, Batya, and David G. Hendry. 2019. *Value Sensitive Design: Shaping Technology with Moral Imagination*. Cambridge, MA: MIT Press.

Friedman, Batya, David G. Hendry, and Alan Borning. 2018. *A Survey of Value Sensitive Design Methods*. Boston Delft: Now Publishers Inc.

Friedman, Batya, Peter Kahn, and Alan Borning. .(2006.). "Value Sensitive Design and Information Systems." In *Human-Computer Interaction in Management Information Systems: Foundations*, edited by P. Zhang and D. Galletta, 348–372. Armonk, NY: M.E. Sharpe.

Gero, John S. 1990. "Design Prototypes: A Knowledge Representation Schema for Design." *AI Magazine* 11 (4): 26–26.

Hoven, Jeroen van den, Pieter E. Vermaas, and Ibo van de Poel, eds. 2015a. *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values, and Application Domains*. Springer Netherlands.

Hoven, Jeroen van den, Pieter E. Vermaas, and Ibo van de Poel. 2015b. "Design for Values: An Introduction." In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values, and Application Domains*, edited by Jeroen van den Hoven, Pieter E. Vermaas, and Ibo van de Poel, 1–7. Dordrecht: Springer Netherlands.

Jack, Hugh. 2013. *Engineering Design, Planning, and Management*. Academic Press.

Johannesson, Paul, and Erik Perjons. 2014. *An Introduction to Design Science*. Springer International Publishing.

Kroes, Peter 2012. *Technical Artefacts: Creations of Mind and Matter: A Philosophy of Engineering Design*. Springer Science & Business Media.

Kroes, Peter, and Meijers, Anthonie, eds. 2001. *The Empirical Turn in the Philosophy of Technology.* Research in Philosophy and Technology 20. London: Elsevier/JAI Press.

Kroes, Peter, and Ibo van de Poel. 2015. ″Design for Values and the Definition, Specification, and Operationalization of Values.″ In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, edited by Jeroen van den Hoven, Pieter E. Vermaas, and Ibo van de Poel, 151–178. Dordrecht: Springer Netherlands.

Latour, Bruno. 1990. "Technology Is Society Made Durable." *The Sociological Review* 38 (1): 103–131.

Malerba, Franco, and Luigi Orsenigo. 1997. "Technological Regimes and Sectoral Patterns of Innovative Activities." *Industrial and Corporate Change* 6 (1): 83–118.

Manders-Huijts 2011. What Values in Design? The Challenge of Incorporating Moral Values into Design. *Science and Engineering Ethics*, 17(2): 271–287.

Meijers, Anthonie (2009). *Philosophy of Technology and Engineering Sciences*. Vol. 9 of *Handbooks of the Philosophy of Science*. Series editors Meijers, Anthonie, Dov Gabbay, Paul Thagard, and John Woods, eds.. Elsevier.

Morrow, David R. 2014. "When Technologies Make Good People Do Bad Things: Another Argument against the Value-Neutrality of Technologies." *Science and Engineering Ethics* 20 (2): 329–343.

Nissenbaum, Helen. 1998. "Values in the Design of Computer Systems." *Computers and Society* 28 (1): 38–39.

OECD/Eurostat 2018. *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation*, 4th ed. The Measurement of Scientific, Technological, and Innovation Activities. OECD Publishing, Paris/Eurostat, Luxembourg.

Pahl, Gerhard, and W. Beitz. 1996. "Engineering Design: A Systematic Approach." *MRS Bulletin* 21 (8): 71.

Pahl, Gerhard, W. Beitz, Jörg Feldhusen, and Karl-Heinrich Grote. 2007. *Engineering Design: A Systematic Approach*. 3rd ed. London: Springer-Verlag.

Parsons, Glenn. 2015. *The Philosophy of Design*. 1 edition. Cambridge, UK: Polity.

Poel, Ibo van de. (2015). "Design for Values in Engineering." In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, edited by Jeroen van den Hoven, Pieter E. Vermaas, and Ibo van de Poel, 667–690. Dordrecht: Springer Netherlands.

Rose, Ellen 2012. "Not 'Just a Tool': A Triadic Model of Technological Non-Neutrality." *Educational Technology* 52 (1): 17–21.

Sachs, Angeli, Claudia Banz, and Michael Krohn. 2018. *Social Design*. Zürich: Lars Müller Publishers/Museum für Gestaltung Zürich.

Vallor, Shannon. 2016. *Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting*. New York: Oxford University Press.

Verbeek, Peter-Paul 2005. *What Things Do: Philosophical Reflections on Technology, Agency, and Design*. UniversityPark: Pennsylvania State University Press.

Verbeek, Peter-Paul. 2011. *Moralizing Technology: Understanding and Designing the Morality of Things*. University of Chicago Press.

Vermaas, Pieter E., Paul Hekkert, Noëmi Manders-Huits, and Nynke Tromp. 2015. "Design Methods in Design for Values." In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, edited by Jeroen van den Hoven, Pieter E. Vermaas, and Ibo van de Poel, 1–19. Dordrecht: Springer Netherlands.

Vermaas, Pieter E., Peter Kroes, Andrew Light, and Steven Moore, eds. 2008. *Philosophy and Design: From Engineering to Architecture*. Springer Netherlands.

Vermaas, Pieter E., and Stéphane Vial, eds. 2018. *Advancements in the Philosophy of Design: Design Research Foundations*. Springer International Publishing.

Vincenti, Walter (1990). *What Engineers Know and How They Know It.* Johns Hopkins University Press.

Von Schomberg, René (2013). "A Vision of Responsible Research and Innovation." In *Responsible Innovation. Managing the responsible emergence of Science and Innovation in Society*, eds. Richard Owen, John Bessant and Maggy Heintz, 51-74. Wiley.

Von Wright, Georg Henrik. 1965. *The Varieties of Goodness.* Routledge & Kegan Paul.

Wendel, Stephen. 2013. *Designing for Behavior Change: Applying Psychology and Behavioral Economics*. 1st ed. Sebastopol, California: O'Reilly Media.

Willis, Anne-Marie, ed. 2018. *The Design Philosophy Reader*. Annotated ed. Bloomsbury Visual Arts.

Winner, Langdon. 1980. "Do Artifacts Have Politics?" *Daedalus* 109 (1): 121–136.

Xu, Zhenning, Gary L. Frankwick, and Edward Ramirez. 2016. "Effects of Big Data Analytics and Traditional Marketing Analytics on New Product Success: A Knowledge Fusion Perspective." *Journal of Business Research*, Designing implementable innovative realities, 69 (5): 1562–1566.

Ylirisku, Salu, and Mattias Arvola. (2018). "The Varieties of Good Design." In *Advancements in the Philosophy of Design*, 51–70. Springer.

NOTES

[1] The term "social design" is also used to refer to engineering design activities aimed at solving social problems.

[2] Instrumental goodness is akin to what Von Wright (1965) has called instrumental goodness: the goodness of instruments or tools of type *X* as type-*X* instruments. For example, if a drill (or other object) is good as a drill (i.e., performs the drilling function well), then it has instrumental goodness as a drill. See also Ylirisku and Arvola (2018), who distinguish various meanings of the term 'good design.'

[3] While 'prudential goodness' or value is usually attributed to persons and relates to their well-being, I use it here in a broader sense, to denote value that can benefit (contribute to the flourishing of) any kind of thing that can be benefited.

[4] This thesis refers to the impact neutrality of technological products. There is also a neutrality thesis that refers to value neutrality or moral neutrality, e.g., Morrow (2014).

[5] The approach of Responsible Research and Innovation (Von Schomberg 2013) is also directed at ensuring technological innovations that make a better fit with society and provide more social benefits. It is an overall strategy toward the research and innovation system that includes design as only one element.

[6] For a few values, such methodologies have been developed to some extent, both for the conceptual and embodiment design phase. For example, in the approach of privacy by design (Cavoukian 2012).