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DESIGN AND TECHNOSCIENCE – WHAT'S UP WITH RESPONSIBILITY?

K. Kornwachs

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1. Can design be done as a scientific activity?

"Quia parvus error in principio magnus est in fine, secundum philosophum ..." (A small error at the outset can lead to great errors in the final conclusions, as the Philosopher says ...) [Aquinas 1225].

Today, nearby every discipline has been converted into a "science" according to the epistemic idealizations of Natural Sciences. The borderlines between the pure or epistemic sciences on the one hand, and the action sciences or applied science on the other hand have become fuzzy. Thus all disciplines have more or less theoretical, empirical and practical issues as well.

The very beginning of this concept of science can be found at the grandfather of Philosophy of Science, Francis Bacon (1561-1626):

"Human knowledge and human power meet at a point; for where the cause isn't known the effect can't be produced. The only way to command nature is to obey it; and something that functions as the cause in thinking about a process functions as the rule in the process itself" [Bacon 1863].

It is interesting to see the more negative statement: Ignorance will make the effect fail. The other way around, the knowledge of the cause would not yet guarantee the effect, but at least it makes it possible. Then it is said that nature will only be defeated by obedience. Obedience means here to see what nature does, to listen to it, to watch it exactly. This is not obedience within the context of command and control, but the attitude to look or to carefully listen to what one can do with nature and what not.

The decisive point is already given here: An observed cause-effect relation ($A \rightarrow b$) is transferred to an applicable mean-goal relation (B per A). Nevertheless, the experience of a successfully applied mean-goal relation as a rule is one of the preconditions of the discovery of causal relations. In analogy to social experiences, Bacon recommended to bring the things in distortions in order to recognize their true structures:

"In the business of life, the best way to discover a man's character, the secrets of how his mind works, is to see how he handles trouble. In just the same way, nature's secrets come to light better when she is artificially shaken up than when she goes her own way."[1]

Thus, it is only possible to observe the true nature of nature by interventions. At least at this point it is not meaningful to strictly distinguish between basic research and pure science on the one hand, and applied science and technology on the other hand. Instead, we use a rather sliding distinction between epistemic and action science. Both types of science have variable portions of theoretical, empirical and practical or operative issues.

Definitely, the natural sciences belong to the epistemic sciences. Here we have three demands:

1. Ideally, the replicability of an experiment as a paradigm for repeatability of experiences at all.
2. The reproducibility of the result within the realm of comparability and pre-defined probabilities.

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[1] ibid., I, Aph. 98, p. 34.

3. The internal consistency of the theory. If the theory is described in terms of mathematics, this consistency can be expressed by freedom from contradictions.

In the action sciences, however, we have the following requirements:

a. The replicability of the tests [Kornwachs et al. 2014].
b. In action sciences, the reproducibility of the experimental result corresponds to the repeatability of a successful action in technology and arts. All that what can be built only once, which only works once, which is only once there, is not applicable and for technology.
c. The internal consistency of the theory corresponds to the successful connectivity of technological rules to other ones. This might be called concatenation. This is the requirement for the coherence of technological knowledge – by the way a necessary but not a sufficient condition that old and new technologies may work together [Kornwachs 2012].

The usual ideology was, that rules in action science could be deduced from laws or regularities in epistemic sciences, i.e. that we could logically conclude from the requirement (1) to (a), from (2) to (b) and (3) to (c). In this view design would only be a kind of art, or – even if computer supported – a kind of craft. A deeper analysis, delivered by Philosophy of Science and Engineering has shown us, that such simple and direct relationships do not exist. They can only be pragmatically hypothesized within the contemporary "scientification" of technology. Nevertheless, these relations are very successful pragmatic rules, the importance of which nobody would deny. The relations can also be converted: Very often we deduce from the replicability of a test to the replicability of an experiment we can perform due to a successful test. This is the pragmatic "conclusion" from (a) to (1). The repeatability of a technical construction would be a prerequisite for the reproducibility of the result of an experiment; this is an analogous inference from (b) to (2). The fact that technological rules can be successfully concatenated, i.e. their consistency, lets hope to find an internal consistency of the underlying theories. This is the strategy to proceed from (c) to (3).[2]

Both directions to make conclusions are logically forbidden, but pragmatically very useful. If it is given, that A always leads to state B ($A \rightarrow B$), this is an if-then statement. This is the common form of laws and regularities in epistemic sciences. The mean-goal relation, expressed as rule "B per A" is a kind of users guide for action, but it presupposes the feasibility of the operational implementation of A. This syllogism is a pragmatic one, not a logical figure [Bunge 1967], [Kornwachs 2012].

Starting from the side of the if-then statement ($A \rightarrow B$) as a natural law or a phenomenological regularity in social studies or in economics, then this statement can be a candidate for formulating a functional hypothesis, that B can be reached per A, shortly "B per A". This is a hypothetical rule and it can be tested. A rule is not true or false, but effective or not. The truth of a law is not yet a proof of the effectiveness of a rule and therefore no guarantee for any technological control. In any case, we have to test the functional hypothesis by putting A into practice. Its functional hypothesis represents a kind of test template. Thus, every design drawing, represented graphically or virtually by an algorithm is an implicit instruction to make an artefact.

Conversely, of course, a test of an observed technical effect, successfully carried out, can be a candidate for the formulation of a scientific law, but this must firstly be confirmed by an experiment. Both directions are important. Therefore, it is significant that every science can act for another science as an ancillary discipline. According to this conceptualization, we can consider design as a scientific activity, fulfilling the requirements (a) to (c). As an action science it contains more empirical and practical components, but new findings cannot be excluded when testing the functional hypotheses. Thus, design also can play the role of an ancillary science, but as a discipline in technology, design comprehends a lot of ancillary science to be successful: This runs from physics, mathematics, computer science, and technology up to ergonomics, sociology, psychology, aesthetics and fine arts.

Whilst practical design seems to be only a matter of technology and engineering, the study of possibly alternative design is a task for the technological sciences. Yet today, design is done in a scientific and computer aided way as never before. The thinking in alternatives requires that the practical design has become also a scientific, not only a practical task.

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[2] In fact, the form of the so-called abduction $(A \rightarrow B) \wedge B \rightarrow A$ is logically not correct, but a useful strategy to find functional hypotheses in technology [Mildenberger 2006].

There is one track we can observe: The help of computer, starting with computer aided design up to computer aided modelling, presupposes the expression of design issues in a kind of a programme, i.e. formal language. This is a prerequisite to implement design models on the computer and to handle with them operatively with the help of software. Whereas we can imagine impossible objects like the Escher triangle in our mind, no software can design and handle it. The possibilities to represent issues with the help of computer programs are limited by the requirement of the freedom from contradiction.

This limitations are also the borderlines for design as a scientific activity.

2. Technoscience as the science of technology

"The technological sciences establish the cognitive requirements for technological innovation and the application of technological knowledge, and provide us with a basis for considering the impact and repercussions of technology" [Kornwachs et al. 2014].

Here we call the set of technological disciplines and sciences technoscience. We speak about Engineering and Technology as multi-facetted disciplines. The same holds for design, of course. With this definition of acatech [2012] in mind, we take a look on Design Thinking.

Taking serious the definition above, we may presume not only, that the development of technology trivially influences the development of the society, but also that the developments within the society do strongly influence the development of technology. Thus, technoscience must contain also social sciences and humanities. This insight has lead to the establishment of institutions like living labs, to the Science, Technology and Society (STS)-Programs at technical universities, and on the theoretical level to concepts like Design Thinking. Although this concept is vaguely defined, it shows the complexity of the design process, if one concedes, that not only technical or economical issues would be decisive for the outcome of the design process and for the structure of the process itself.

Numerous aspects has been integrated within the genuine activity of design: not only aspects of research, observation and understanding of technology, wishes of clients and boundary conditions of economic requirements, but also the developing and handling of (new) ideas in an exploratory and sophisticated manner. This includes their concrete implementation up to the modelling and the prototyping. At the end of this way, just this implementation is not always necessarily connected with new ideas. Nevertheless, in nearby all cases learning processes can be observed in a great variety. This variety of activities also occurs beyond the activities in the design professions, i.e. wherever creative productions take place and where they must be indeed implemented (cf. [Simon 1969, 1996], later [Curedale 2012]).

Design as a discipline of technoscience takes place in a certain triangle. If talking about innovation and technological development or about scientific and technological progress, three types of agents play in the game:

- The protagonists, i.e. those people who invent new products and processes, who develop them, and who want to bring them to the market (inventors, developers, investors).
- The users or consumers: Their buying behaviour of new products and the prospective usage of new processes make an offered product or process to an innovation (market success).
- Reports and reporters: i.e. those people who retrospectively identify such a development as innovation, based on specific criteria, not discussed before.

In view of this complex situation, Design Thinking has not really won any practical relevance, since societal theories mostly assume that technological developments do not only ground in natural potentials of the human, in anthropological factors or in technological potentials: Here, the history of technology development is understood as primarily dominated by social relations and generally paradigms of values on the one hand. On the other hand, economically oriented approaches emphasize the pre-orientation of possible paths of technological developments through rationalizing maxims such as cost savings or profit maximization. It is difficult to find a proof for the one or other assumption in empirical research or in history of technology (cf. not yet published study in [Kornwachs 2014, 2015], also [Stabe and Wolf 2003], [Kollek 2013]). Another hypothesis is that factors, influencing the paths are usually not due to a fictitious universal economic rationality, but rather to some organizational peculiarities (this path dependency is discussed in [Foray 1997], [Arrow 2003], [Windeler 2003]). Moreover, one may win the impression, that if very often people advocate a certain technology track as a key technology for future economic prosperity, this may stimulate innovative breaks.

In their early stages it is often hard to see whether, and if any, how future technologies will arrive at a mature state. In other words: Talking about future technologies could possibly induce a success, and sometimes people prevail with that.

3. Design thinking and the Mode 2 of science

Traditionally, design has been conceived as a specific discipline together with other academic disciplines. Design develops future things (artefacts), bringing them forth from the things which are before-hand in the actual present. Design is a part of this whole process; i.e. it is upstream to the process of production itself. Design decides on forms and functions - particular in connection with questions of aesthetics. Nowadays, the possibilities of user orientation come into the scope as well as the consideration of essential human needs. [3] Here, a traditional pattern of academic disciplines comes to light, according to that new knowledge will only be generated from current and previous knowledge. Moreover, this knowledge must be able to be concatenated with the previous knowledge. For design as a discipline it means that actual design always builds on previous designed and already shaped artefacts. Thus, there would be no really new creation. This has been called the Mode 1 of science.[4]

The term "Mode 2 of science" was coined by Helga Nowotny [Nowotny et al. 2003], in order to distinguish the traditional structures of science, which are characterized as hierarchical, disciplinary, homogeneous and academic, referred to as Mode 1, from a new way of doing research and science. In mode 2, there is no longer a separation between scientific and social actors. In short, science as well as technological development is seen as social and institutional events. Science in Mode 2 is anti-hierarchical, heterogeneous, and transdisciplinary, it focuses on the social responsibility for the consequences and side effects of research and developments. The quality of science is not only evaluated in a pure intra-scientific mode, but the justification of spending budgets doing research must be based on criteria of social relevance and social costs. This has lead to the well-known, increasing evaluation pressure on the one side. On the other side we can recognize the commercialization and global commodification of science as a social practice.

The Mode 2 of science integrates knowledge about theoretical and empirical conditions, knowledge about phenomena and facts as well as knowledge about norms, values and goals. Together with knowledge about technical practice and knowledge how to shape and design, we also have implicit or tacit knowledge that we cannot formalize and model completely (introduced by Polyani [1966], see an extended study in Mildenberger [2006]). This fact has already influenced the engineering design methodologies and tools in practice. One of the approaches was the Design Thinking already mentioned. It reflects the conditions and presuppositions in which contexts of categories and mind styles design is done in concrete situations, groups, and interests. Nevertheless, this way of thinking is broadly discussed, but is not been implemented pratically, even not in institutions like Living Labs (cf. [Patnaik 2013], [Kornwachs 2015]).

4. Responsibility in science[5]

Together with this Mode 2 in science the question of responsibility arises. Beside the respect of social and legal issues we can state a close coupling between the responsibility in technoscience and the responsibility in technology itself and its practices. If it is possible to win knowledge about the conditions of design, the designers are responsible for the quality of their constructions on the one hand and for suitable institutions in which they can work in a responsible way on the other hand.

The first fundamental problem that arises in connection with designers responsibility is how to classify the multiple relationships involved: who is responsible for what, why are they responsible, to whom are they responsible to, how long should their responsibility last and which values and criteria are the basis to specify these relations? These questions are structurally the same as the question for responsibility in technology and technoscience. With respect to practical issue, we can ask also which sanctions can be taken. How the problem of reliability can be handled?

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[3] This includes ergonomic, cognitive, social, emotional, and aesthetic needs.

[4] This corresponds to Mode 1 of generating and processing knowledge; cf. [Nowotny et al. 2003].

[5] This section has been pratially adapted and modified from [Kornwachs et al. 2014, p.6].

In German Philosophy of Science and Engineering, an extended debate has taken place since the 1990ies. This discussion has nonetheless proven to be valuable, since it has demonstrated that the definition of responsibility needs to be separately specified for every situation and problem (cf. [Hubig 2003], [Kornwachs 2012], [Kornwachs et al. 2014]).

There is a clear distinction between two types of responsibility: The one type involves liability issues and criminal penalties. For example a chief designer at a manufacturing company continues to be held responsible for the recall of a faulty product in the automotive industry even several years after the event. The other type is the responsibility of the technological sciences towards society as a whole for the consequences of technology, and e.g. for the education of young scientists. We cannot discuss these problems all in details, but we try to apply these reflections to the situation of the designer and the design process.

Those who are responsible for a good design play a triggering role for planning and implementing engineering projects with the design products and processes. Thus, they are constantly confronted with the challenge of designing something that can deliver the desired benefits of the users as well as the economic requirements. Moreover, harmful side effects should be avoided. The difficult trade-off between benefit and harmful consequences remains also for the inventors and designers. The concepts of Mode 2 of Science as well as the attempts to conceptualize these problems by the means of the framework of Design Thinking recommend an ongoing dialogue with society. Scarcity has been always a source of efforts towards innovations as well as changing social needs. In turn, social needs are constantly growing as technology opens up new horizons. Thus we need a continuous stream of really new technological solutions.

There can be no doubt at all that the application of the scientific method, including the formal methods supported by computers, to design and to develop technology have largely caused the proliferation of creative solutions and improved safety and reliability of technological products and processes.

Nevertheless, it will never be a perfect design, and mistakes will inevitably be made in science and technology. It is the special responsibility of all scientists, particularly engineers and designers, to ensure the success and safety of our technological world, despite technology’s inevitable imperfections. At the same time, their professional competence obliges designers as well as engineers to inform society about doubts and uncertainties. As such, designers as technological scientists are not only responsible for producing optimally functioning, user-friendly products, processes and technologies. They are also responsible to design such that natural resources are used both economically and sustainably. Designers, technological scientists as well as practising engineers are obliged to preserve the options, open for the future. This includes that the shape of technologies should preserve the conditions for responsible behaviour of all people involved [Kornwachs 2000]. This principle is an ethic recommendation, going beyond the categorical imperative of Kant. Nevertheless, it can be only applied if these conditions are known.

5. Reversibility design

As a consequence of this responsibility, it is not enough to design products with respect to sustainability, to user friendliness as well as to the suitability for Industry 4.0. A responsible shape of technology requires also error friendliness and reversibility.

This can be derived from the principle of conserving the condition of responsibility. One of these conditions is to act freely, i.e. not to find oneself in a dilemmatic situation. A dilemmatic situation has at least two options to act; both of them are leading to (morally or otherwise) inacceptable consequences. Thus, many customers and users of cell-phones are forced to accept additional functions they cannot avoid, or they are urged to accept business regulation with respect to data protection. If they could prevent it, they would never agree upon.

Another condition to act in a responsible way is to be well informed about the artefact and to be able to handle a technology. If the information is not available or if it is hardly to understand, errors and malfunction will take place. Since the modern technology is complex, and for a layman not or not easily to comprehend, there is a certain probability that the reliability of technical function decreases with the complexity of the artefact. Thus, error friendliness should be a paradigm, better respected than in former times.

Finally we take a look to large scale technological systems. One of the striking examples is represented by the global problem of nuclear waste management. Even if we would stop all nuclear power plants now, the problem will persist for a very long time. But we have other problems, too, e.g. the electronic waste management. To design technology in a responsible way means that we should invent and reinvent technologies that can be “removed”. The importance of this idea may become clear, when we realize, that we are surrounded with technologies we cannot give up, or we can only refrain from their use with a lot of disadvantages. Exactly this circumstance may lead into dilemmatic situations, proved to be unfriendly to user and society. Therefore, designers should feel responsible to look for such technologies which can be “switched off” without disadvantages for the user. This may be one of many ways to enable designers, producers and customers to act in a responsible way with given and future technologies.

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Prof. Dr. phil.habil. Dipl. Phys. Klaus Kornwachs
University of Ulm, Humboldt Study Center for Humanities
Strickers Hoehe 22, 88260 Argenbuehl, Germany
Email: klaus@kornwachs.de