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JUSTIFICATION OF JUSTIFICATION: THE CASE OF TECHNO SCIENCES

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1. The systematic problem

The starting point of Vyacheslav Stepin's (2005: p. IX) reflection on the philosophy of science is the Vienna Circle and criticised as an idealization, because it excluded "practical activity, philosophy, culture and [… the] historical development". He then picks up "post-positivist conceptions", mentioning Karl R. Popper, Thomas S. Kuhn and Imre Lakatos. He continued by studying the structure of knowledge dynamics, as imbedded in the historical process of scientific discussions "immersed in a changing sociocultural development". My contribution today has a similar aim, but focuses on the concept of justification as the central part of each scientific methodology and aims especially at techno science. The main problem will be the justification of justification – the question of how arguments in cases of Kuhnian paradigm shifts are justified, since they intend a new kind of justification. As this takes place on a meta-level, which Stepin (2005: p. XII f) calls "infrastructure", consisting of "sociocultural factors", in my approach termed *world view* in a neutral sense, it will be necessary to develop the basic elements first. The next step questions whether the results concerning the natural sciences can be used for the techno sciences as well – or how we have to extend the discourse.

The systematic problem of justification became important following the results of the *history of science*: Stepin (2005: 1ff) speaks of the difference between "traditional and technogenic civilisations". In order to see *new* items (in the world as well as in theoretical imagination), someone must be open-minded; moreover, to accept a novelty, there must be openness among scientists as well as society. This is not self-evident because non-scientific cultures normally suppress such novelties as senseless or dangerous; Joseph Needham (1969: 190–217) showed this with respect to China, which missed the European conditions to develop new sciences and technologies during the Renaissance period in order to keep the rules constituting the society stabile. Discovery is thus bound up with cultural preconditions right up to the world view, which has to be considered: So, the history-dependent ability to make discoveries as a *quaestio facti* has to be taken into account.

The same holds for the *quaestio iuris*, i.e. concerning justification, namely, for changes of theories. Remember the struggle between the geocentric and the heliocentric system from Nicolaus Copernicus up to Galileo Galilei, of the unification of electricity and magnetism as electrodynamics proposed by Hans Christian Oersted, or Albert Einstein's proposal of his theory of relativity. Therefore, historical changes concerning the contexts of discovery as well as of justification must find their place.

The systematic problem in the *philosophy of science* might be highlighted by a hint from Kant (1786, Preface), who defined science as follows: "A science is each system of cognition, ordered by principles". A system of *cognition* – i.e., something which necessarily presupposes justification, for (since Plato) knowledge differs from belief not only insofar as it is true, but as it is justified. Discovery is no justification. Moreover, the history of a discovery, too, even if we would use a Lockean theory of knowledge, which seeks a foundation via the genesis of knowledge: The history of an error would not transform it into truth. We have learnt from Kuhn that justifications themselves have a history and depend on paradigms. Therefore, the history of a justification is no justification at all. This is the new post-Kuhnian problem: What about the *justification of justification*? This indicates that we need a kind of systematic order, including the indicated elements.

2. Conventions, contingency, and truth

Since Rudolph Carnap (1922: 33ff.) analysed conventions of measurement, and since Kuhn (1962) showed the conventional character of paradigms behind each scientific approach, we know that conventions belong to the inevitable preconditions of science. This has consequences for the methods of justification, – leading up to the danger that there is no truth in the sciences at all, but mere convention (therefore, Paul Feyerabend's 'Everything goes' (1970) is taken literally by post-modernists). Indeed, there are conventions that, as a bundle, constitute the paradigm. Stepin (2005: p. XIII, extended p. 374) calls them "a picture of the world (disciplinarian ontology) and a 'scheme of method' presented by ideals and norms of investigation". Others have picked out special cases, which I have brought together for my purposes as the following commitments (Poser 2001: 186–199; 2nd ed. 195–208) in order to indicate the structural elements of any science:

1. *Ontological commitments* concerning the fundamental objects and relations of them in a scientific discipline (Stephan Körner 1970; for examples, see Stepin 2005: 295f, who calls them "disciplinary ontologies").

2. *Sources of knowledge* as accepted logical and mathematical means, observations, experiments, etc., including the instruments that are permitted in this context (Yehudi Elkana 1981).
3. *Hierarchy of these sources*, e.g. empiricists and rationalists quarrelled about the priority of experimental data vs. rationality (Elkana 1981; Stepin speaks of a hierarchy of theories).
4. *Judicial commitments* concerning the methods of proof giving, supporting, corroborating, rejecting or falsifying a proposition (Kurt Hübner 1978; Stepin's (2005: 377) 'constructive justification'.)
5. *Normative commitments* concerning e.g. beauty, simplicity, or apodictic truth (e.g. of axioms) etc. of a theory (Hübner 1978).

Some short explanations: These commitments differ enormously from one science to the other and even for sub-disciplines: Nuclear physics presupposes an ontology differing from classical mechanics. – Chemistry uses other kinds of experiments as knowledge sources than physics. – In theoretical physics, mathematical methods own a priority as a knowledge source compared with experimental physics and its experiments. – Judicial commitments vary considerably: A mathematical proof differs radically from an experimental corroboration of an empirical hypothesis. Yet, even within mathematics, we find sharp differences between the intuitionistic, finalist and classical approaches, all of which differ entirely from proofs given by means of computers, as occurred in the Four colour theorem. – The normative commitments include a wide and quite open collection of fixations, which have an enormous influence; one might think of the idea that a sufficient theory has to be laid down in a system of axioms.

Within the framework of commitments, the judicial ones are the most important because science is seen as the best kind of well-founded knowledge we possess. This seems to be destroyed by the conventional and paradigm-fixed character of judicial commitments: Remember that, according to Kuhn, a paradigm shift is a kind of conversion, not a rational decision, because paradigms are incompatible. These commitments are transformed throughout history, so that science seems to be a purely contingent undertaking, far away from justified truth, since it depends on a bundle of mere conventions. Yet, characterizing the sciences by means of just these commitments is helpful for a solution of Kuhn's incompatibility thesis: In the light of these commitments, one can exactly localise the differences between an old and a new paradigm; this indicates, at the same time, that only a small part of the rules, fixed as commitments, will be substituted. It is crucial that this substitution be based upon *arguments*, even if these arguments cannot rest on the rules of the commitment to be modified, but on a meta-level. So, the difference between the Ptolemaic and the Copernican approach concerned nothing but the formal structure of the theory, whereas all the objects of the ontology – earth, moon, sun, fixed stars, wandering stars (planets) and all observations – remained untouched. The justification for the formal change depended on the normative commitment that God's ideas are simple: the Copernican way for calculating the position of astronomic objects was just one procedure, whereas the Ptolemaic tradition needed three independent mathematical steps for solutions.

Thinking of paradigm shifts, Stepin (2005: 283ff) distinguishes between 'intradisciplinary' and 'extradisciplinary revolutions'. Kuhn examined only the first kind of shifts, which took place, e.g. when Ptolemaic astronomy was substituted by Copernicus. The second case consists in bringing together two seemingly incompatible theories; Stepin's example is the unification of quantum mechanics and relativity theory. Moreover, Stepin (2005: 306) points out that "the foundation of sciences was not an act of immediate change of paradigm (as Kuhn wrote), but a process which started long before direct transformation of investigation norms and the scientific picture of the world". Yet, in any case, we are confronted with the necessity of modifying or substituting elements of the commitments that constitute the discipline or disciplines in question. Therefore, it is more adequate to say that those changes depend on a justification by means of a meta-level – and seen from the side of the old paradigm, this is *always* an extradisciplinary revolution because the discipline at a time *t* is constituted by the commitments at *t*.

As already mentioned, science historians show that scientists themselves have always *argued* in each case of paradigm shift: They never followed quasi-religious conversions, but gave rational and well-founded reasons for their decision to change the content of one of the commitments, including those concerning justifications. Furthermore, Kant (CPR B 83 ff) has already clarified that a universal criterion of truth is impossible, for in order to be universal, it must be purely formal, whereas true propositions concerning the world always have content. Therefore, one needs criteria referring to contents. This is the dilemma of each method of justification: It aims at truth, but we can never formulate universal conditions as time-independent criteria. To put it philosophically: Truth is taken as a regulative idea, and all criteria of justification are defended by pointing at this idea in trying to elaborate criteria referring to the contents in question. Meanwhile, justifications aim at a meta-level justification of the new justification commitment.

Therefore, the new and unexpected challenge of history as well as of the philosophy of science consists in a clarification of this meta-level, which is responsible for new concept formations and theories outside traditional boundaries, but bound up with the regulative idea of truth and with elements of a time-dependent world view, that is, with metaphysical elements or convictions of how to fill the gap between a purely formal idea and a phenomenal content. Clarifying the ways of justifying justifications will be one of the most central problems of the philosophy of science.

3. How to localize the meta-level of justification

Stepin (2005: 378) sees the outcome today as a global scientific revolution, characterized as a 'post-non-classical rationality'. But this is what happens after having accepted the new view, whereas the problem we are dealing with pertains to the way in which the new view was accepted.

Let us call the scheme of commitments a scheme of *Basic Rules*. Together with the laws of a science they constitute the scientific "wold picture" or "Weltbild", as Stepin (2002: 29–11) calls it. Now we seek a scheme of *Meta-Rules*. In order to be able to localize it, one needs a broader area of discourse. First of all, we have to include the area of *sciences as systems of propositions*, since this is the outcome of knowledge under the criteria of the science-specific basic rules. Yet, between these systems of propositions on the one hand and the basic rules on the other, we have to include the *acting of scientists* because they make observations and deductions, develop theoretical generalizations guided by these rules and, in doing so, aim at propositions that will be accepted by the scientific community, since they are in accordance with the methodological tools.

The next element that must be included is the way in which the sciences are used in society. In this context, it is helpful to distinguish between two types of use put forward by Jürgen Mittelstrass (1982), namely, *knowledge for the sake of orientation* and *knowledge for the sake of action* ('Orientierungswissen'/'Verfügungswissen'), in short, orienting knowledge and action knowledge. One might think, e.g. of astronomy giving us a cosmic orientation, whereas chemistry allows us to manage chemical processes. Actions are provoked by human *needs*, leading to better conditions of life, whereas orientation knowledge is demanded not only for morality but also for the localization of human beings. For instance, consider the English version from Goethe's *Faust*: "So that I may perceive whatever holds / The world together in its inmost folds". Let us call it the *ontic imagination*. This has to be seen as a task for not only humanities or literature, but also theoretical physics and genetic biology.

Both kinds of knowledge and, consequently, all scientific propositions and theories are imbedded in a global area, the *world view* – not in the sense of an ideology, as it is normally connected with the German term 'Weltanschauung', but in a neutral sense, yet depending on and including the cultural background of a time – and thereby restricted to a time and a region. This world view includes the ethical and ontological doctrines or convictions.

All these elements were transformed systematically by the sciences in both respects, namely, concerning action possibilities as well as orientations. But important for the basic rules of science is the fact that the world view at the same time is the reference figure for them. This is immediately clear for moral principles, which are included in the normative commitments relating to actions of scientists and, in some cases, even for the motivation or the interdiction of the development of kinds of experiments or theories. Yet, in any case of paradigm shift that must now be seen as a transformation of one or more commitments within the basic rules, the meta-level of argumentation depends on meta-rules that are in accordance with the world view. Therefore, it is necessary to introduce a cluster of meta-rules, namely, of second-level commitments. An example: In 1905, a young and unknown man from Zurich, named Einstein, without a PhD, without a post at the university, sent to the famous *Annalen der Physik* a paper that was completely incompatible with classical physics (in fact, the first part of the special relativity theory). The board accepted it, even though had someone sent a new proposal for a perpetuum mobile, they would have defeated it. What were the reasons for accepting such a paper that was not scholarly due to narrow criteria? The criteria in question could not belong to the judicial commitment of standard physics. Therefore, they have to be seen as belonging to a meta-level as a commitment of meta-justification.

Science and world view

It will be extremely difficult to identify such meta-level commitments clearly, even if we collect cases of paradigm shift in the history of sciences. This has been done, but the outcome is less than a patchwork, far from a well-structured area. A typical example is the Leibniz-Newton controversy on space and time. Following the Cambridge Platonists, Newton took space and time as absolute entities. ‘Absolute’ – that means ‘divine’, and Henry More had argued that space and time have more than 20 divine properties, such as infinity, ubiquity, inseparability, unity, etc. Leibniz argued by means of the principle of sufficient reason: If such an infinite space and an infinite time did exist, then God would have no reason at all to localize the creation in it somewhere; therefore, these are nothing but relational concepts. Newton then used the bucket argument, which is incorrect, even if Mach rather than Leibniz provided the counterargument. In both cases, we find in common metaphysical presuppositions understood as part of the world view. In fact, physicists followed Newton’s physics in the 18th century, but they skipped the metaphysical background and restricted physics to a description without explanation. This was indeed a paradigm shift that went back to the world view. It was only Einstein, who picked up the question anew and under differing world view conditions. This discussion is continuing today: thinking of big bang against steady state, of black matter against modifications of the Minkowski structure, and so on.

Seeking common ground between these and other examples, we might say that they coincide at several points, which can be seen as the stabilizing base. They seek grounded knowledge within a systematic context. This includes:

◊ an argumentative approach even in going back to the world view,
◊ a systematic approach,
◊ an analytical view of the problem, and a corresponding synthesis of analytically gained results.

This shows that truth as a regulative idea is the motivating background of all scientific undertaking.

4. The case of techno sciences

Is it possible to adapt the structure of the sciences to the techno sciences – or do they depend on a completely different arrangement? If techno science consisted of nothing but the application of natural sciences, we could transfer all the results from the philosophy of science in its mainly physicalistic orientation to techno science. But this would be misleading: Whereas the natural sciences want to describe nature, the techno sciences intend to change the world; or, to put it differently, scientists seek the most universal laws, whereas engineers seek better ends (Poser 2010). Stepin (2005: 34) explains, that "a need for scientific-theoretical technical knowledge was initiated by practical necessity, when with solution of concrete problems engineers could not solely rely on the acquired knowledge, but were in need for scientific-theoretical justification of creating artificial objects, which is impossible without a matching technical theory, worked out in the technical sciences."

The consequences are evident, when we ask for the first-order constitutive commitments as Basic Rules in techno sciences:

1. The *ontology* of techno sciences consists in *artefacts*. But this is much, much wider than in the case of any natural science because it has to include all types of objects of all these sciences, seen as mere objects. From the very beginning we have to include artificial processes. Moreover, there are artificial material substances and material objects. We have to include artificial chemical processes. There are living beings from genetically manipulated bacteria to sheep like Dolly, or cyborgs such as human beings with a pacemaker, and finally 'immaterial technological objects' (Faulkner/Runde 2012) as the content of a computer program. This differs completely from the natural sciences because the disciplines of the latter work within differing clear-cut ontological realms.

But even this is not enough: The ontology needs a fundamental connection of its objects. Here, we note a further difference between the natural and the techno sciences, since the former depend on properties and the latter on *functions* as a means-to-an-end relation. These ends rest on individual and societal needs that open the universe of discourse from the very beginning. Techno sciences are intimately connected with society.

2. The *sources of knowledge* differ from those of the natural sciences. *Observations* and *experiments* are not purely theory-directed, as Popper puts it with respect to the sciences, whereas in the techno sciences they are *aim-directed*, namely, concerned with societal needs that have to be fulfilled. Moreover, in most cases, the techno sciences do not speak of experiments, but of *tests*. Whereas the experiments of natural science are conducted under idealized conditions, technological tests show that a construction observing very special circumstances meets the expected conditions. These conditions depend on *values* such as stability, functioning, safety, etc., which indicates that they belong to or fulfil a means/end relation, namely, the function. – A further type of knowledge source is based on multifunctional *models*, namely, theoretical ones, computer-simulated ones and material ones. Models are used in the sciences as well. One might think of Bohr's atomic model, or of the atomic models in chemistry. Yet, they are used there as a visualization of a structure description, whereas in the techno sciences they are used as models *of* something or *for* something. Models of something are employed in *technology* in cases where a direct approach to a process or an artefact is impossible, so that the model is needed to analyse and understand per analogiam what is going on. In *techno sciences*, models are applied on a theoretical level to gain a calculable knowledge of the essential behaviour of a technological system. In this case, very different elements are represented in a generalized way to determine whether they fit together. – Models *for* something have been used in history, e.g. as a presentation of a ship design in order to demonstrate the project. In techno science, we observe the broad use of feasibility studies that develop possible ways of designing and its consequences for society and the environment. The important point in all these cases is that abstraction, analogies, creativity, theoretical and practical knowledge and, especially, values from different areas come together (narrow technological ones such as functioning, economic ones such as profitability, humane ones such as safety and health, and global ones such as societal postulates or ethical principles).
3. The *hierarchy of sources of knowledge* cannot depend on an apriority of experiments, tests or models, and it cannot be substituted by the universality of theories, as Stepin adequately sees it relating to natural science. The techno sciences differ from the natural sciences since any approach is finally interwoven with societal needs. This does not imply that the approach of SCOT, the Social Construction of Technology (Bijker/Pinch 1987), is the only correct one, since they omit technological categories entirely. So, the hierarchy depends on a temporal equilibrium between technological and societal elements.
4. The *justification* in techno sciences is by no means the theoretical corroboration of abstract theories, since the objects in question – even gene-

ralized technological propositions – are always imbedded in societal needs. This has a far-reaching consequence: In the natural sciences, explanations and justifications depend on the Hempel-Oppenheim scheme of explanation (Hempel/Oppenheim 1948), which can be extended to the confirmation of hypotheses as laws of nature. But in the techno sciences, we use the Aristotelian practical syllogism as Georg Henrik von Wright has analysed it for explanations of actions (1963; 1972): *P* wants to reach *A*. In order to reach *A* one has to do *B*; therefore, *P* does *B*. It connects an aim *A* with the means *B*. In the techno sciences, this is generalized as a relation between types of means and types of ends, namely, functions, expressed in structural *rules*, whereas the reliance of such ends on societal needs is the constitutive fix point, coming from the outside. This indicates that the justification rests on two different steps: The first one depends on empirical data, corroborated by tests or by models, and concerning functions formulated as rules, depending on an aims-to-an-end background; the second one is a justification of an end by corresponding norms or values.

5. This shows that *normative commitments* have an enormous influence on all of techno science. They consist basically of technological norms, which are not merely – as at the beginning of 20th century – a standardization of shrews or colours, etc., because today they include safety norms for craftsmen, workers and users, health norms for the society, and ecological norms for the environment. Therefore, they mirror even ethical values. Beneath these fixed norms incorporating existing values, we find explicitly formulated postulates by societal groups or laid down in decisions or laws by the government: These are the impulse or the gear for the development of technological problem solutions as an answer to societal needs.

Looking back, we can say, on the one hand, that the characterization of the techno sciences by means of the structure of Basic Rules commitments can be done fruitfully; but, on the other hand, the characterization of these commitments differs deeply from the case of natural science because societal needs, coming from the outside, influence each part, as they are the source for each problem to be solved, whereas the problems of a natural science are always brought up internally by the development of the science in question. One of the most fundamental differences consists in seeking rules instead of laws. As a consequence, the techno sciences seek a different kind of truth. Their leading regulative idea is: The proposition "Rule *x* is approved in practice" must be true.

Results from the classical disciplines of natural sciences as auxiliary sciences are picked up and used within the techno sciences insofar as they can be treated as an explanation of functions, so that they get a part of the rule. Herein, we observe an intense amalgamation of scientific, technological and normative rationality. Therefore, techno science is the most important case of Stepin's (2005: 378) "post-non-classical rationality", which "extends the field of reflexion on activity. It is aware of the relation not only between the knowledge of an object and the specific nature of the means and procedures of activity, but between this very knowledge and the structure of the goals and values of such activity as well. At the same time the relation between intrascientific and extrascientific goals is brought to light." So, the differences that have just been shown between natural sciences and techno sciences are the substantiation of Stepin's characterization of post-non-classical rationality.

5. The justification of justification in techno sciences

What about the justification of justification against this background? As we have seen, the necessity of such an approach goes back to cases of a paradigm shift. One must admit that the difficulties, as formulated by Kuhn, hold for the techno sciences as well. There have been paradigm shifts in the history of technology that have simultaneously mirrored corresponding changes on the theoretical level. Examples include the switchover from systems of working machines driven by one central power engine to separated electric motors and, more recently, the substitution of classical petrol motor cars by electric cars. Most of the examples used today concern information technology. Günter Ropohl (1998: 49–87) characterizes the paradigm shift in the techno sciences by the switchover from construction science to system technology, which integrates many areas and includes the reflection on societal aims. In each case, the development of completely new systems had been necessary, which presupposes changes in the corresponding techno sciences.

Furthermore, we observed that the justification of the new approach happens on a meta-level. These changes can depend on ground-breaking innovations such as, e.g. electro magnetism, laser, LED, in electrical engineering. These offer new functions, which cause a revolutionary change within the discipline in question. But *inventions* as such are not enough, as is shown by the fact that approximately 95 % of all patents have never been used, neither in technology, nor in the techno sciences. What is needed for a breakthrough is the acceptance of the created objects (or its imagination) by customers, i.e. by society. This is why Joseph Schumpeter's concept of *innovation* has to be introduced, since it concerns those new elements that are accepted within society. Therefore, we have to extend justification by social needs as an argument within the structure of the practical syllogism.

As we all know, societal needs themselves keep changing. They can be manipulated by advertising. They might depend on what a government believes to be necessary, on postulates of national or international norms, or even on what people believe to be the best choice for them. In most cases, this will be the reason for paradigm shifts. There is a company named "PTS – Paradigm Shift Technologies Inc." in USA and Canada, which promises "achieving the unachievable", seeking "solutions to the growing need for unique and environmentally friendly coating technologies" (PTS: …/about us/our history). This indicates how technologies follow societal needs in a way that allows using Kuhn's concept of the paradigm shift successfully in advertising. In fact, there are hard analyses of technologic paradigm shifts, since knowing their conditions would allow predictions concerning the market development. The connection between techno science and societal needs has been analysed by means of the so-called *TAM* – Technology Acceptance Model – (see Davis 1985; for critical remarks Bagozzi 2008), but it belongs to commercial information technology or information management, which would be too narrow for our purpose. Concerning Instructional Technology, which means the synthesis of education and communication technology, Timothy Koschmann (1996: 3) explicitly went back to Kuhn and intended to show "that the shifts that have occurred in *IT* [Instructional Technology] were in fact driven by shifts in underlying psychological theories of learning and instruction". His conclusion is that paradigm shifts "come from outside the field" and "are always difficult to foresee" (p. 19). This implies that *TAM* models aiming at economic predictions are quite senseless.

All of this shows the problems behind a paradigm shift in techno science: It is a development that is going on together with a technological paradigm shift, since technology today needs techno science. Moreover, as Stepin points out, this is no immediate change, but a process. In any case, this is connected with or depends on a paradigm shift in society, which means a change in the unwritten rules constituting society (from moral rules down to 'needs', such as to own a mobile phone with a camera, WLANE, etc., like all my peers). The process of changes in these rules depend on or go back to problems that are seen as pressing ones, so that they become driving forces. If some technology seems to be a promising candidate to solve the problem in question, the pressure of the society will be the justification of this technology in its changes of the basic rules of the techno science discipline in question. But it would be wrong to see it in this way from goal setting to goal striving as a monocausal development for at least two reasons: First, goals are quite universal, and there are uncountable means to such an end. Second, the important point is how goal setting happens. Thus far, I have spoken about societal needs as if they were given, but they might depend on a societal problem that needs to be solved, which itself is the outcome of a process. The need might go back to the fascination for a new possibility, or simply be caused by advertising. These different pushes leading to new technologies are taken as a justification of the shift.

Nevertheless, we might interject by saying that this is a process of development of technologies corresponding to the market, but neither depends on paradigm shifts (even if they are called so in the public), nor do they normally affect the techno sciences. In fact, real paradigm shifts in techno science need a justification. This happens in normative discussions on energy sources, health and ecology as well as concerning the question of which kind of so-called key technologies should be supported at universities of technology. In all these cases, we observe a justification via societal reasons. So, we note a justification concerning the promotion of a special new techno science that, in a second step, has to open the way of the techno-scientific constructive justification, as Stepin named it. The entire procedure is what Stepin has called an extra-disciplinary revolution, but in an even more radical sense. However, the interesting difference between the meta-justification concerning the natural sciences and techno science is clear: In the natural sciences case, scientists themselves argue for new topics (ontology), knowledge sources (methodology) or justification, and these arguments are based on the world view and the regulative idea of truth. In the techno science case, the arguments stem from society and its institutions; they centre on human needs and are supported in the end by moral reasons. This is a new phenomenon, mirrored by the historical development of industrial norms, now including humane norms. It shows that the philosophy of techno science has the new and eminent philosophical task of cooperating in this justification of justification: Responsibility for a humane world must form the background of all technological development on earth. This must be the leading principle of our "technogenic civilization culture", as Stepin (2005: 123) calls it.

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