Science in the Context of Application: Methodological Change, Conceptual Transformation, Cultural Reorientation
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I Research Going Practical: A Break with the Epistemic Past?

Ever since Francis Bacon societies have looked to science to provide answers to its practical problems and to inspire useful applications. However, science didn't live up to these expectations until some time in the 19th century. Since then the situation has changed drastically. Science is viewed today as an essentially practical endeavor; it appears inextricably interwoven with technology and heavily intertwined with the economy, politics, the media and other realms of society. We increasingly view the world around us as a product of science and technology. Accordingly, we have begun to appreciate that science does not take its problems only from nature and then produce technological applications, but rather that the very problems of scientific research themselves are generated by science and technology. Simultaneously, current issues like global warming, the toxicology of nanoparticles, or the discovery and use of renewable energies are constituted by many factors that interact with great complexity. Science in the context of application is challenged to gain new understanding and control of such complexity—it cannot seek shelter in the ivory tower or simply pursue its internal quest for understanding and gradual improvement of grand theoretical schemes.

This markedly practical orientation of research is claimed to have a significant impact on the institutional and methodological characteristics of science. In terms of the goals that are pursued, university research in the sciences nowadays increasingly resembles research in industrial laboratories. Both public and private institutions define research problems chiefly in terms of practical projects. This attitude contributes to changes in the institutional system of science. Universities found companies in order to market products based on their research. Companies buy themselves into universities or conclude large-scale contracts concerning joint projects. With respect to methodology, the emphasis on intervention is sometimes claimed to push theoretical representation into the background. Shaping the world, rather than understanding it, appears to be the chief objective of contemporary science.

The ever-increasing practical relevance of science, its technological ambitions to manage the complexities of highly developed societies, and the heavy application pressure under which it operates have prompted a flurry of analyses which converge on the claim that the scientific enterprise as such has undergone a profound methodological and institutional transformation during the past decades. The goal of the group has been to identify characteristic institutional and methodological changes in the past half-century, and to clarify whether it is really warranted to interpret these changes as a major, epoch-making realignment of science and technology in society.

II Changing Conditions of Scientific Research

It is undeniable that science is intensely involved in technological progress, economic growth, emerging risks and risk perception, and even public culture. Yet it is in no way clear how such entanglements in turn affect the scientific enterprise. For instance, the credibility of science itself could be a casualty. To the extent that science is intertwined with social issues or becomes part of political power play, the scientific claims to objectivity and trustworthiness tend to be attenuated. The loss of objectivity in the dual sense of empirical adequacy and interpersonal neutrality is striking and obvious in the field of expert testimony where scientists are frequently accused of pursuing vested interests and where the expert is confronted with the contrary judgment and the divergent advice of the counter-expert. However, a contrary intuition is rooted in the view that superficial knowledge will eventually fail to support technological progress. Conversely speaking, the theoretical integration and the causal explanation of a phenomenon are expected to improve the prospect of controlling its properties and to put it to reliable use. The same goes for the risks associated with science. In applied fields of inquiry, error may spawn grave non-epistemic consequences and may cause harm beyond the walls of laboratories and libraries. Technological intervention that is at once both reliable and safe is achieved best by relying on knowledge that has passed tough standards of quality control.

These considerations outline a field of contrasting intuitions as to the methodological features of applied research which was explored by the research group. The interest of the group was attracted, in particular, by the various ways in which science and technology interact in the context of application. Only the first one of the following items is in conformity with the traditional picture of technology as applied science.

- Scientific research creates new technical capabilities which are then developed in engineering contexts.
- Technological innovation gets ahead of scientific understanding and prompts research activity to attain comprehensive understanding of its basic principles, be it to better manage the technology, or to gain fundamental insight from technologically produced phenomena.
- Piece-meal research activities manage complexity of socio-technical systems with no expectation of comprehensive understanding as in, e.g., nanotoxicology or foresight knowledge.
- Technical instruments are used to conduct research and to produce novel scientific insights but are not liable to comprehensive theoretical penetration. The most prominent example concerns computer simulations which are ‘epistemically opaque’ in a number of respects.

As for institutional conditions, application-oriented research is to a large extent conducted in industrial companies, and it is important to understand the institutional features of commercialized research or ‘science in the private interest’. For instance, one relevant constraint is the commitment to secrecy which restricts part of industrial research. Research outcome is produced but kept behind closed doors, a feature which is apt to hide possibly dangerous side-effects and also tends to reduce the level of scrutiny to which the results are put. By contrast, a number of companies recognize that laboratories operating behind a veil of sequestration are cut off from the benefits of cooperation. Consequently, attempts to suppress the circulation of results usually backfire and often damage those responsible for trying. In fact, a large number of published articles originate from private research sites.

III Science, Values, and Society

A related question of great relevance concerns the impact of science on society. What kind of challenge does science, as it is practiced and understood today, pose to society? Here, the selection of research topics is of critical importance. Three mechanisms are operative: disciplinary, market-oriented, and public interest. Disciplinary topic selection is the procedure usually attributed to basic research. Research unfolds within an advanced theoretical framework from the more simple to the more complex. This internal mode of topic selection is contrasted with an external mode in application-dominated research. Problems are imposed from outside of science according to their practical relevance. One effect is that research tends to comply with customer demands; commercialized research thrives on serving the interests of many people. Still, a bias produced by a market-based procedure of topic selection arises from its inherent limitation to customers' needs and profitable goods. A disturbing trend in medical research, for instance, is that neither the health-related ailments of developing countries nor exercise programs rank highly on the research agenda. Research into matters of public interest is not guaranteed by either one of the mentioned modes of topic selection. If science is expected to take up problems of public relevance, it needs to be actively supported by public institutions. It follows that not all forms of the politicization of science are detrimental to science or to society.

Another question of the research group concerned the interrelations between science and social values, and between freedom of research and accountability. Restrictions on research violate the freedom of research which is widely accepted as a vital intellectual value and a precondition of creativity. Thus, a certain tension seems to emerge between the demand for the social accountability of science and the commitment to freedom of research. Different approaches to coming to terms with this challenge were discussed, ranging from institutional procedures for setting the research agenda democratically to emphasizing the ethics-based duty of individual scientists to accept responsibility for the foreseeable consequences of their work. The importance of a dialog between science and society was universally agreed upon—though different forms of their interconnectedness were envisioned.

IV Exploring Science in the Context of Application

It is an important challenge to explore how science and culture are affected by these influences and developments. As a first step, the research group looked into contemporary research practices. Application-dominated and epistemic or truth-oriented research was compared with regard to the role of fundamental theories, the nature of confirmation procedures, the structure of models, simulations, and experiments. Questions pursued here include: Do application-dominated research projects exhibit novel, characteristic methodological features? Can the new research practices be described with the traditional methodological vocabulary and do the research results measure up to received standards of trustworthiness? What are the changing interpretations of the relationship between science and technology? Is it true that the distinction between representation and intervention becomes blurred with respect to the object of research and the objective of research?

The second step concerned the interrelations between science and society and, in particular, the impact of science on society. Here some of the questions posed included: Is the fear that a science subject to strong social, political and economic pressure will lose its critical role of 'speaking truth to power' justified? Can it be expected that science increasingly becomes participatory and enters a state of a social science of nature? Are we facing a tendency toward the privatization of knowledge with an emphasis on intellectual property rights or can one diagnose the persistence of the Mertonian norm of 'communalism' according to which scientific knowledge is and remains in public possession?

In the third step, the questions outlined at the beginning were taken up: Do the observed changes amount to a cultural transformation? Is it warranted to interpret these changes as a major, epoch-making realignment of science and technology in society? The understanding of science within society and the self-understanding of science are at issue here. What are the perceived relationships between science and society, science and nature, and science and technology?

Thus, the three central questions were: Does science proceed differently, and if so, how? Does science affect society differently, and if so, how? Is science conceived differently, and if so, how?

V The Mode of Operation of the Research Group

These issues were addressed from a variety of disciplinary sources, in particular philosophy, sociology, history, cultural studies, and working scientists. Resources from within the philosophy of science were invoked for analyzing the epistemic procedures used in different social configurations and for illuminating the general cultural impact on science. Likewise, analytical tools from the sociology of science were drawn upon for charting the intricate territory of diverse institutional settings as they emerge in present-day society and for capturing the various social forces that act on science. The history of science was of crucial importance for dealing in offering insight as to whether the philosophical and sociological characteristics that were identified before are really novel or turn out to be familiar features, perhaps in a different guise. Cultural studies contributed to illuminating the role of visions and imagery in the development of science. Finally, these respective analyses of science were confronted with the experience and understanding of the practitioners themselves, i.e., scientists working under the heavy pressure of practical challenges and social demands.
The research group adopted a two-pronged scheme for organizing its work, with weekly seminars on the one hand, and monthly workshops on the other. In the seminars, fellows presented their contributions to the research groups, and working scientists, or 'scientist informants', adumbrated their points of view. Such practitioners, who conduct research in the context of application, offered their experience and understanding as a touchstone for the analyses and claims emerging in the group. In addition, a series of ten thematically focused workshops (see reports in former issues of the ZiF: *Mitteilungen*) formed the intellectual backbone and the institutional innovation, of the research group. These workshops centred on the work of a small number, usually two, of the relevant scientists or scholars. Their work was intensively discussed after the preparatory seminar meetings. These workshops provided the topical red thread for the work of the research group and advanced its research endeavors considerably.

The list of workshops gives a good impression of the way the group approached the common theme. After two preparatory meeting in February and July 2006, the group started in October 2006.

October 26 – 28	**Opening Conference: 'Science in the Context of Application: Transformations of Academic Research'**
November 27	**'Getting Started'**
December 15	**'Science and Technology'**
January 22	**'Representation, Control, Complexity'**
April 16	**'Science and Social Values'**
May 2 – 3	**'Engineering Theory'**
May 4	**'Science and Media'**
May 23 – 24	**'History of Scientific Policy Advice'**
June 4	**'Commercialization and Commodification of Science'**
June 18	**'Institutional Fragmentation of Scientific Research'**
July 6	**'From Lab to Field: Transforming Research Practices'**

September 27 – 29 **Final Conference:**
'Science in the Context of Application'

Another noteworthy event included the ZiF photo competition on "Science in everyday life" that was co-organized by the research group. The award ceremony took place during the final conference and a number of submitted photographs were shown at an exhibition at the ZiF (see I / 2008, January 2008, ZiF: *Mitteilungen*).

VI Results and Conclusions

As expected from the beginning, the wide range and diversity of disciplinary approaches posed challenges to the communication and the mutual understanding of the group members. This may well be characteristic of interdisciplinary research groups in general, but here the inherent divergence went deeper than usual in that the very issue and goal of the research group itself was under dispute and seemed to depend heavily on particular disciplinary—or even sub-disciplinary—viewpoints. Care, considerateness, and diplomacy were sometimes needed to stay on the tracks of a balanced analysis. A diverse collection of views and opinions were constantly present within the group from the beginning to end, and accordingly some conclusions of the research group were more widely agreed upon than others. Some of the pivotal results include the following.

There was confirmation that the application of a scientific theory in no way resembles a deductive chain but rather demands the construction of 'mediating models' which do not only contain laws and boundary conditions (as it was thought traditionally) but also additional conceptual elements, such as rules of experience, approximations, correction factors, or parameters that can only be read off from the data. Consequently, such models rely to a considerable extent on extra-theoretical assumptions, and their construction may require a large amount of ingenuity. As a result, technological innovations are not produced in a top-down fashion starting from high-brow theory. Putting knowledge to use is a creative process which needs a familiarity with a wider range of principles, regularities and facts. Nevertheless, models constructed for this purpose are typically shaped conceptually by the pertinent theories, although their empirical outcome is largely determined by the non-theoretical factors mentioned. The conceptual grid is supplied by theory in the majority of cases, while the interstices are filled by observation. Interestingly enough, this general pattern was found to apply to large areas of epistemic science as well.

Furthermore, application or the search for utility proved in general compatible with the search for truth or understanding. The reason for this compatibility is that truthful regularities or well-understood phenomena usually provide a better basis for intervention than mistaken assumptions or brute regularities. Therefore, striving for practical relevance does not, in general, undermine the credibility or trustworthiness of science. Utilitarian values do not necessarily drive out epistemic ones.

The resulting impact of technology on science is highly significant, too. New technical tools such as computer simulation or scanning tunnelling microscopes with a resolution at the nanoscale prompt the emergence of new fields of research that lie at the intersection of classical engineering and academic natural sciences, such as materials science or nanoscience. The immense increase in the speed of calculation and novel techniques of visualization also create new explorative spaces. These spaces can be probed by computer simulations that make it possible to deal with models in a quasi-experimental fashion: interpreting the simulation model can be found out by varying the pertinent parameters and observing how the model behaves on the screen. Hence, new instrumentation and new fields of research emerge together (see the paper of Paul Humphreys in this issue for more information).

Among the more controversial issues was the claim that science has recently taken on a 'technoscientific mode' of methodology. Advocates of this idea claim that science was traditionally associated with the quest for truth or with uncovering nature's machinery. This scientific enterprise is separated from technology, which is dependent on theoretical penetration. The 'technoscientific enterprise', then, is claimed to have proceeded into an 'engineering mode'. What matters are capabilities or skills, that is, the creation of robust technical systems. The technoscientific project in the methodological sense relevant here is characterized by the notion that theory is subservient to technology or that understanding nature is taken in the service of intervening in nature.

The contrary position adopted by the research group denied that such a historical break has occurred recently. Rather, the scientific enterprise characterized in the foregoing manner, was claimed to be a historical myth. The scientific and the technoscientific enterprises came into the world united. The scientific enterprise, rightly understood, was said to be distinguished by connecting truth and utility, or even by taking scientific knowledge as a means for achieving a betterment of the human condition. This entails that the technoscientific break in the methodological respect relevant here occurred in the midst of the scientific revolution.

Another controversial issue was whether a 'technoscientific turn' has occurred at the ontological level, that is, concerning the objects of scientific research. It was stressed, on the one hand, that the traditional notion of nature can be upheld: part of nature is what humans didn't create. The contrary position emphasized that nature in this restricted sense in no way exhausts the scope of the natural sciences. Nature that is subject to scientific research transcends by far the realm of what exists independently of us. The technoscientific turn at the ontological level means that most of the entities and processes addressed by scientific research are not found or uncovered but are rather created. The hole in the ozone layer, the onco-mouse, or nanotubes would not have come to exist by nature left to its own devices. They are deliberately produced by humans, but explored like objects generated by the whims of nature.

The two aforementioned types of relationship between science and technology are, first, that science is instrumental in producing technology, and, second, that technology is used in gaining new knowledge about nature. The rise of technoscience means that a third mode has gained ascendancy. Technologically produced entities or processes have become the objects of scientific scrutiny. We have made them but we fail to understand their causal or nomological properties. Such objects are human creations but they offer surprises just as objects untouched by human hands. They need to be studied scientifically in order to be understood.

Nature that is subject to scientific research transcends by far the realm of what exists independently of us. The former now includes the emergent properties and unforeseen side-effects of our own creations. Traditionally, nature was often regarded as a creative force; now, it is we who create nature. The technoscientific project at the level of ontology entails that when we look into nature what we see is mostly a reflection of our own works. The world has become a mirror of humankind.

VII The Impact of the Research Group

After the completion of the residential period at the ZiF, the group has continued to work out their results and conclusions, and to bring them into a publishable form. Three books of different types are being planned that will present and summarize the results, each addressing a different audience.

The first of these is an essay volume, which is intended to address the question whether we are currently witnessing an epistemic break in science. This volume will be edited by Alfred Nordmann, Gregor Schiemann and Hans Radder. The volume will start with a defense and a critique of the break thesis to which fellows will offer critical comments. This volume will be directed to a wider, non-specialized audience.

A second book-in-progress is an edited volume that collects the scholarly papers that emerged in the context of the research group, fellows and other scholars that have been part of the process, in conferences, workshops or seminars. The volume will be edited by Martin Carrier and Alfred Nordmann and will provide new perspectives on the methodological, institutional and societal dimensions of research in practical contexts. The chief topical foci are ‘changing conditions of scientific research’, which comprises the influence of society on scientific research, and ‘science, values, and society’, which addresses the impact of science on society. A third book is being planned that will address assumed recent institutional changes in science. Hans Glimell and Werner Rammert will edited a volume on *Science Institutions Re-Configured: Traversing Disciplines—Transmuting Regimes* which will collect contributions from fellows that have been working on the institutional issues and from several scholars that had been connected to the group during workshops and conferences.