Physics is Part of Culture and the Basis of Technology

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Abstract

Fundamental aspects of modern life owe their existence to the achievements of scientific reason. In other words, science is an integral element of the modern world and simultaneously the epitome of the rational nature of a technical culture that makes up the essence of the modern world. Without science, the modern world would lose its very nature and modern society its future. Right from the start, physics forms the core of European scientific development. It is the original paradigm of science, the foundation of technology and a constitutive part of a rational culture. It will remain a model methodological discipline in the future and its strengths will be used fruitfully in interdisciplinary and transdisciplinary collaboration.

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1 Physics and culture

Science and culture are not antithetical. It is far more the case that science is culture by its very nature. Attempting to sever the ties between science and culture would itself be a de-civilising phenomenon, i.e. an expression of lack of culture. Both science, which would lose its cultural essence, its cultural nature, and culture, which would lose essential aspects of its rational form, would be the poorer. The world would try to revert to other cultural forms, without science and technology. However, any such attempt would not advance the modern world, but destroy it. The reality of the world, its cultural and technical reality, is quite simply also the reality of scientific reason. There is an indissoluble link between its development and the development of the world - a world that builds with scientific and technical bricks.

Cultural reality also includes the reality of the educated intellect. Education is merely the other side of culture: culture turned into an (individual) way of life. And, in a world that is to an ever-increasing extent the result of scientific reason, this also means that science itself is part of education. Contrary to what many people believe, science cannot be the opposite of education or even simply something completely different to education. Although the notion of the European age of Enlightenment, that only the scientific consciousness was truly educated, has lost its validity, this does nothing to change the fact that, in the modern world, science, and particularly the natural sciences, constitute cultural reality and hence education. If education was what the natural sciences are not, then it would be the property only of the educationalists and arts scholars who study it and (occasionally) attempt to manage it. Education would then lead us out of the world in which we live and not into it - as is always the task of genuine education. This is, incidentally, why it is also so important for natural sciences to remain a compulsory part of our school reality.

The fact that these are not superfluous remarks is made clear not only by the reality of our current education and training system, which is notorious for neglecting the natural science subjects, but also by those who talk about “two cultures”, meaning the scientific culture, on the one hand, and the arts culture, on the other, with education appearing to be part of the latter. According to this position, having read Shakespeare would be education, while knowing the second law of thermodynamics would not.

There is no doubt that this attitude bears witness to a lack of understanding of education, albeit one that is widespread. Anyone who breaks down the world according to educational aspects such as this, has already lost the modern world. So, it has to be understood once again as a unity. And, under the headings of culture and education, this unity includes the natural sciences - and the phenomena studied in these subjects - just as much as the arts. But it would seem that many arts and science scholars, who have now settled comfortably into the two-culture distinction, still have to learn this. In addition, scientists will have to show more clearly than to date through their work that their actions and their knowledge are also part of the cultural and hence the educational form of the modern world.

Everything that can be said in general about the relationship between science, the modern world, culture and education, is particularly true of physics. Physics shares the cultural character of all sciences and is, at the same time, as the foundation of a technical culture that makes up the essence of the modern world, the first among all the sciences. Without physics, there would be no technology and also no scientific orientation to find theoretical, methodological and instrumental expression in terms such as law and explanation and, at the same time, to describe the architecture of the world in categories of space and time.

2 The history of physics

The specific nature of physics as the basis of technology and constituent part of a rational culture is reflected in its history. It was the Greeks who discovered the possibility of science, the possibility of viewing the world with scientific eyes, and it was natural philosophy in which their eyes were opened by rationality. It was only a small step from Milesian natural philosophy, that bade farewell to a mythical conception of the world, to Aristotelian physics. This, in turn, was considered until the sixteenth century as the paradigm for the development of a scientific theory to explain the world and, at the same time, as the realisation of the idea of the unity of Nature. The essential constituents of this philosophy were (1) a theory of elements and a theory of natural loci (the elements) with the cosmological result of a geocentric system, (2) the hypothesis that the prerequisite for any change in locus or speed is the existence of an acting force, and (3) the division of the cosmos into a sublunar component, the subject of terrestrial physics, and a superlunar component of pure harmony of the spheres, the subject of astronomy. With Aristotelian physics, humankind began to place itself in an ordered and explicable world. In this sense, physics and philosophy were also one and the same.

Aristotelian physics, with its structures, both causal and teleological, determined by goals and purposes, and an Aristotelian world describable by these structures, was followed by Newtonian physics and a Newtonian world, in which all that remained were heavy masses moving in absolute time through an absolute space, where the stability of the world, i.e. equalisation of the energy losses, was a matter for God. At the same time, the "mechanism" of the Newtonian world, expressed in the mechanics of gravitational movements, determines not only a grasp of inorganic Nature but also, in the form of what is referred to as "Newtonianism", an understanding of the organic, psychological and social cosmos. Once again, the unity of Nature expressed in Newtonian physics also forms a unity of scientific understanding.

The situation becomes more complicated with the emergence of electrodynamics with Faraday and Maxwell. This is expressed, for example, in the fact that now, as well as material bodies, fields are also seen as part of the make-up of the world. This initially makes a unified understanding of Nature more difficult but, in the final analysis, encourages it. One path followed by Ostwald and others in pursuit of this goal was the study of energetics, inspired by the important developments in thermodynamics. Here, energy, which shows itself in various forms and is capable of conversion, became the sole, fundamental substrate of Nature. Although this programme could not be implemented satisfactorily and tended to be misleading - and was, moreover, very highly infiltrated with ideology - it nonetheless remained committed to the old idea of the unity of Nature.

In the course of the history of science, this situation only changed again with the introduction of Einsteinian physics, particularly the general theory of relativity. In this pioneering theory, the dynamic geometry of the space-time structure of the world, which is regarded as a single unit, is indivisibly linked to the force of gravity. The world described by physics now becomes invisible. Nonetheless, this Einsteinian world, like the Newtonian world, still remains largely deterministic (although this point is disputed among interpreters of the general theory of relativity).

Complementary to this view of the world stamped by the macrocosmos, we see the development of quantum mechanics and the Copenhagen interpretation thereof, deriving from the puzzles of the atomic world. Indeterminism rules in large sections of the microcosmos, and sometimes also at the mesoscopic level (the Heisenberg world). It, too, exhibits its intangible effects, particularly in terms of the measuring process of quantum mechanics. It is also quantum mechanics that initially makes a unified understanding of the world a more and more remote possibility. New fundamental forces, such as strong and weak interactions, were discovered in the 1930s and 40s. It became clear that these forces stubbornly refuse any sort of conceptual link to gravity. The existence of the two new fundamental forces also makes it clear why the attempt made by Einstein and others to find a uniform, geometric formulation for electrodynamics and the general theory of relativity was bound to fail. Today, the standard model provides a splendidly confirmed unified theory of electromagnetic interaction with strong and weak forces. However, the force of gravity has not yet been incorporated. Modern approaches, such as the superstring theory are once more picking up this ambitious goal ("Einstein's dream"); it will be interesting to see how these attempts alter our view of the world.

Regardless of specific theory formulations in physics, it is true to say that the further it moves away from the Aristotelian world, the less concrete it becomes, while at the same time becoming more applicable in terms of many individual results. The technology that is changing the world today and turning it into a technical culture, is the offspring of the classical physics of Newton, Clausius and Maxwell, on the one hand, and of modern developments, particularly in quantum physics, on the other. But physics still remains the paradigm of an "empirical philosophy" (Kant) or an empirical science and, at the same time, the paradigm of a scientific culture, combining the maximum of theoretical abstractness with the maximum of applicability. However, in more recent developments, its relationship with the other natural sciences is changing. The hierarchical relationship, with physics as the undisputed parent discipline forming the conception of the world, is increasingly being replaced by a cooperative relationship. But in this new relationship, physics is once more gaining importance from methodological and other points of view.

3 Transdisciplinarity and the future of physics

Two aspects are likely to play a decisive role in the further development of physics. Firstly, the most significant problems to be studied and the research programmes based on them will increasingly be those dealing with topics situated between subjects and disciplines, where skills and competencies in more than one subject or discipline will be a prerequisite for the work involved. Pertinent examples of interdisciplinary or transdisciplinary research programmes of this type can be seen in the most recent developments in the field of nanotechnology. The structures investigated in this context fall within the domains of three disciplines in the natural sciences; physicists, chemists and biologists are working together to understand and produce objects with dimensions in the nanometre range. We need only think of the sensational studies on fullerenes (buckyballs) and the no less significant production of microscopic tubes from a few carbon atoms, as well as numerous biologically important macromolecules.

Physicists, chemists and molecular biologists each bring contribute different skills to the laboratory-scale production and analysis of nanostructures. Either they start off with a specified macroscopic structure, e.g. a surface, which they then skilfully process using the methods of physics until the nanostructures they are looking for appear (top-down approach), or they begin directly at the level of atoms and molecules, systematically synthesising increasingly complex structures from this point of departure (bottom-up approach). Another promising approach is to study and utilise the functional properties of extremely small structures that already exist in Nature. All three approaches to nanotechnological research can be seen to be closely interlinked. Progress in one of the disciplines involved generally results in progress in the others as well.

Secondly, interdisciplinary sciences will have a more important role in future and will both inspire the content of the "old" sciences and also bring them closer together. These comprehensive sciences deal with formal structures and concepts that are used in the individual disciplines. Information science must be mentioned in particular here, the results of which fall on fertile ground in the engineering and natural sciences. At the same time, examples, such as bio-computers and quantum computers show that this development also has lasting effects on technology, which is benefiting to a considerable extent from the new knowledge. It is becoming clear that progress in technology is not bound by disciplinary limits. Rather, technical challenges require a bundling of competencies from different fields.

Nature, like technology, also knows no disciplinary bounds. Breaking down Nature into individual fields to be dealt with by specific disciplines is not a natural process, but an artificial one that has arisen historically for more or less pragmatic reasons. It fuels the hope that the whole of Nature will be accessible to scientific investigation. At the same time, there are questions that resist a breakdown of this type. In this respect, it is particularly the transdisciplinary research programmes and the interdisciplinary (structural) sciences that are rejuvenating the old idea of a unity of Nature.

We could ask whether the present specialised, disciplinary order can endure in the long term. As tasks with a transdisciplinary orientation flourish, specialist and disciplinary boundaries are fading. They are losing their former importance against the backdrop of a traditional system of science. Maybe it will also prove useful to set up new disciplines (e.g. nanoscience), in other words to further develop the disciplinary order along the lines of research. What has to be acknowledged, however, is that it is proving very efficient to bring together experts from the given subjects and disciplines to work on a new complex of problems. This may happen on an institutional basis, as in the case of the Center for Nanoscience (CeNS) at Munich University, for example, or it may involve a looser form of cooperation. In any event, concrete problems will in future increasingly be handled by varying forms of cooperation between the sciences. In this context, strong disciplines are a necessary precondition for successful transdisciplinary work. Again, because of its breadth in terms of methodology and content, physics is an ideal partner for other disciplines here.

For this reason, physics will retain its role as a model methodological discipline in the future in three respects. First, the methods of investigation and standards of evaluation in physics, i.e. the methodological criteria of physics in the narrower sense, are an essential guideline for scientific research and will remain so. Second, the development of theories and mathematisation found in physics form a yardstick for all theoretical research. And third, even in the future, research in other disciplines will be carried out with the aid of (measuring) instruments developed by physics for problems that were (initially) exclusively physical (e.g. NMR methods, lithography, etc.). As regards the content of research, the boundaries between the subjects and disciplines will become increasingly open and the methods of one discipline will be increasingly picked up by other disciplines. Even if, in the future, biology and other natural sciences combine with physics to construct a view of the world, physics, as the model discipline as described above, will still remain the theoretical and methodological foundation of the natural sciences.