Studies in History and Philosophy of Science 57 (2016) 64–66

Contents lists available at ScienceDirect

Studies in History and Philosophy of Science

journal homepage: www.elsevier.com/locate/shpsa

The concept of intelligibility in modern physics (1948)☆

Paul K. Feyerabend (1924-1994)

Translated from German by Daniel Kuby and Eric Oberheim

ARTICLE INFO

Article history:
Available online 13 January 2016

Keywords:
Paul Feyerabend;
Erwin Schrödinger;
Anschaulichkeit;
Visualizability;
Positivism

ABSTRACT

This is an English translation of Paul Feyerabend's earliest extant essay "Der Begriff der Verständlichkeit in der modernen Physik" (1948). In it, Feyerabend defends positivism as a progressive framework for scientific research in certain stages of scientific development. He argues that in physics visualizability (*Anschaulichkeit*) and intelligibility (*Verständlichkeit*) are time-conditioned concepts: what is deemed visualizable in the development of physical theories is relative to a specific historical context and changes over time. He concludes that from time to time the abandonment of visualizability is crucial for progress in physics, as it is conducive to major theory change, illustrating the point on the basis of advances in atomic theory.

(Written as an antithesis after a discussion between the philosophy and the science working groups of the *College-Gemeinschaft Wien* of Prof. Schrödinger's paper: "On the Peculiarity of the Scientific World-View".)[1]

In modern physics, it is often said that it is completely impossible to grasp the external world as the philosopher understands this concept. Rather, it is maintained that the physicist, when dealing with a particular lawful regularity, is forced strictly to adhere to the phenomena and to remove all elements that do not have any representation in the phenomena from his mental images [*Gedankenbildern*]. This purely descriptive approach has become known as positivism and immediately fell into disrepute among many philosophers. The following is a brief attempt to set out the foundations of this remarkable method and its epistemological presuppositions.

In doing so, from the very beginning, one can proceed in two different ways—either let physics and philosophy both have their say and listen to the emerging discussion. However, I do not think that much edifying will come from this, not the least because over just this past century there has been a highly significant conceptual shift in both disciplines.

The second approach is more indirect and goes by way of concepts that are generally common in everyday life (which, after all, constitutes the joint starting point of the exact sciences as well as philosophy). We therefore replace [6|7] the conceptual pair (real external world/appearance), which represents our problem in philosophical terms, with the conceptual pair (intelligible/abstract) and see what comes from it.

First, the very concept of intelligibility [*Verständlichkeit*][2] itself: In the natural sciences, one has always attempted to

☆ This is an English translation of Paul Feyerabend, "Der Begriff der Verständlichkeit in der modernen Physik" in *Veröffentlichungen des Österreichischen College*, Österreichisches College: Vienna 1948, pp. 6-10. The German typescript was found in the European Forum Alpbach archives, and the translation appears here with permission from the European Forum Alpbach and Grazia Borrini-Feyerabend. Original page breaks are indicated in the format [n|n+1]. Some terms from the German original are also enclosed in square brackets in the text.

1 See Daniel Kuby's introduction for background on the philosophy and science working groups and their joint discussion of Schrödinger's paper, which lead up to this essay. See Schrödinger, E. 1948 "Die Besonderheit des Weltbildes der Naturwissenschaften", *Acta Physica Austriaca*, 1: 201-245, translated as "On the Peculiarity of the Scientific World-View" in: *What is Life? and Other Scientific Essays*, New York: Doubleday, 1956, pp. 178-228.

2 '*Verständlichkeit*' and its cognates have been translated consistently as forms of 'intelligibility' throughout the essay.

http://dx.doi.org/10.1016/j.shpsa.2015.11.016
0039-3681/

dissolve all of the phenomena accessible to the senses into simple visual models [*Modellbilder*], thus making the gearing intelligible. These models explain macroscopic lawful regularities and do not themselves require further explanation. They are immediately clear, evident, vi sualizable [*anschaulich*],[3] if one may say so. At this point, we can already see that the concept of intelligibility is often almost coextensive with the concept of visualizablility [*Anschaulichkeit*].[4] Yet, in most cases it is not just about whether this or that model can at all be visualized [*angeschaut*] (we will denote this with I), but chiefly which laws it adheres to (analogously, this with II). A chair, for example, that changes its size, if one brings it to different points in a room, is visualizable in the sense of Nr. I. It is not usual for chairs to behave this way, yet the processes occurring can be seen, can be measured, in short, can be visualized. However, visualizable in the second sense means additionally that one expects the visualized objects to behave like familiar things that one is used to. This conception [*Anschauung*] presupposes, in the case of the Greek atomists very primitively, that everything that happens can be traced back to collisions; in the case of classical mechanics, to the motion of attracting masses. In one case, there is a model that became plausible through the behaviour of things in the immediate environment, in another case a conception [*Vorstellung*] that was derived from the lawful regularities of planetary orbits that had already become comprehensible. Viewed from the first standpoint, the motion of the planets and the underlying law seem incomprehensible, absurd, and from the very beginning one attempts to replace it with the tension properties of an intermediate medium. The abundance of theories that appeared at that time, and to whose establishment not in the least even Newton contributed, is a psychologically interesting clue as to how the concept of visualizablility is to be conceived. The dictum of the absurdity of action at a distance tells us nothing about the active forces in the universe. Today, we know that very well. Rather, it tells us something about the way of thinking of those who could not conceive of something other than impact, pull and push, as these were the only types of force action occurring in the immediate environment known back then. Independently of this, Newton analysed the relations of the motion of the planets and determined the law from which all of the planets' orbits can be derived through simple superposition with a constant velocity factor. This was the first practical application of the mode of thought that became generally known today as positivist.

It is very instructive, on the other hand, to look at physics in the 18th and 19th centuries, which analysed the phenomena under consideration from the opposite side in order to dissolve them by way of models [*modellmäßig*]. It is the era of celestial mechanics, in which action at a distance had become plausible to such an extent that one even tried to trace immediately evident phenomena, such as a billiard ball's elastic reflection off a wall, back to complexly structured forces acting at a distance. Laplace's theory of capillary action is the best example of how much the concept of intelligibility is subject to change and how little a theory's unvisualizability [*Unanschaulichkeit*] can be used as an argument against the content of a theory—an argument that certain physicists still put forward against the modern development of the sciences.

Let us summarize:

At a given point, intelligible are those lawful regularities to which one has become accustomed through long use, whose structure is understood from itself; thus, initially lawful regularities in the immediate environment, then those of the directly accessible distant environment (celestial mechanics).

At the end of the last century, one then even tried to obtain models of the lawful regularities of atoms on the basis of celestial mechanics. But from the outset it can already be said that this procedure is no way justified epistemologically, other than by the (heuristically important) principle of continuity; and that in the end success is a matter of chance. For in this case, we dare to suggest no more and no less than that atoms behave exactly like the objects in the world to which we have already grown accustomed; that the laws that our tables, chairs and bathtubs obey as a whole may also determine the emission of spectral lines or the structural conditions of atomic nuclei. If one looks at this hypothesis and all of its consequences, then one may not be surprised if after all, in the long run, certain deviations result that cannot, with all the good will in the world, be made sense of so primitively.

But now the approach itself:

To begin with, we know the atomic weight of atoms through measurements of the density of the elements.

The velocity, and maybe also the rough structure of molecules (spherical, elliptical, dumbbell-shaped), follows from thermodynamics and the molecular theory of gases. The fact that every atom contains the equivalent amount of positive and negative electricity follows from Thomson's experiments. The necessity of repulsive forces from the law of the attraction of electricity. Bohr built a model analogous to the lawful regularities of the planetary orbits, in which the centrifugal force of the revolving electrons takes over the role of the repulsive force required. So far everything is highly visualizable and satisfactory. Yet, the matter already becomes questionable if we continue to consider the conditions of motion [*Bewegungsverhältnisse*] in atoms according to classical laws:

First, every non-uniformly moving charge is the source point of electromagnetic radiation.

Secondly, according to the law of the conservation of energy, the radiation process has as a consequence a loss of motion, so that the atom ultimately ought to collapse under continuous emission.

What speaks against this is:

1) The stability of atoms.
2) The sharpness of spectral lines.

Consequently, this model seems to be useless. But now (principle of continuity), the rescue attempts begin (auxiliary hypotheses):

a) The electron does indeed go around the core, though without at the same time being able to emit radiation.
b) The electron goes only on certain paths (consequence of quantization), so it does not have the capability of planets to trace arbitrary paths.
c) The emission and absorption process has as a consequence a sudden change in direction of the electrons, although without being bound to any specific orbit, that leads the electron discontinuously to a next energy level. [8|9]

With each of the points a), b), and c) a classical law is eliminated. The model is in fact still visualizable, yet only more in the sense of (I). It resembles more a haunted house than a physical edifice.

We see what is going on here:

[3] '*Anschaulich*' can mean clear, evident, graphic or vivid. For more on the various meanings of '*Anschaulichkeit*', see Daniel Kuby's introduction.

[4] '*Anschaulichkeit*' and its cognates have been translated consistently as forms of 'visualizablility' throughout the essay.

The approach of the classical model is necessarily transformed until ultimately nothing of it is left. (Last remnant: Sommerfeld's *Wimmelelektron*.[5])

This raises the question as to whether that anticipation of classical laws is at all suited to lead to a satisfactory conception of the structure of atoms; if we are not here standing before an in principle new domain that cannot be grasped with images taken from the world of tables and chairs; and if it is not methodically more practical first simply to record those lawful regularities, without immediately relating them to a carrier, "*atom*" (however it may be configured).

This is the position of modern physics. One may find it unsatisfactory, just like the Cartesians found the idea of direct action at a distance unsatisfactory, although a little later one thought one understood these lawful regularities. Now, as then, we are dealing with a transitional phase, at the end of which we will feel that a different way of thinking is visualizable and intelligible. Here, like there, all elements of the earlier conception [*Anschauung*] must be completely removed in order to let the new lawful regularities emerge. *This* is the position of contemporary positivism. It enables us to formulate those relationships that will seem intelligible to us tomorrow.

Its course of action is drastic. 'Atom' is not this or that thing, but the sum of phenomena that are known in a particular domain. This is to be understood as follows. The phenomenal differentiation of elements leads to a preliminary primitive classification (periodic system of the first type). More refined investigations, which do however presuppose the identity of the substrate, allow us to find the nuclear shell as the main feature of comparison, according to which the sequence of elementary building blocks [*Elementbausteine*] can be ordered. These elements so-classified are examined with regard to their spectrum and their behaviour within a magnetic field, etc. In this way a series of lawful regularities results that assign the corresponding atomic number to the elements. The sum of all these lawful regularities is then "the atom X".

Now from the laws themselves, certain quantities result that prove to be largely independent of changing external circumstances (mathematically speaking, independent of arbitrary transformations), and which still retain this invariance even when the building blocks of earlier physics have already been through many changes. A well-known example of such a quantity is the interval of general theory of relativity. It may look like the transformation of space and time coordinates (which so far had a meaning independent of velocity) opens the floodgates to all kinds of arbitrariness. Nevertheless, even here there is an admittedly not directly observable quantity that proves to be completely independent of velocity and gravitational deformation. This shows that the objects of our perception cannot be the final invariants and therefore are also not suited for an invariant representation of all natural laws.

Once we have clarified to ourselves these new mainly only mathematically formulable relationships often enough, we recognize [9|10] a completely different kind of simplicity, than was still the case in the classical picture. We fare like a wanderer, who after many visits, has a hitherto completely unknown and strange region in plain view. We understand the new territory from its immanent lawful regularities and have thereby made more progress, than if we would have built a model out of rods and hooks, which after a few runs would have been doomed to stagnation anyway. Admittedly, it is always and everywhere possible to transfer already known relations to newly discovered domains, and in practice—for the sake of continuity (= convenience)—one will initially proceed this way. However, there is no principle that could permanently guarantee the success of this method. For the so-called 'unity of natural forces' only subsists in the respective world view and may be reduced to absurdity by any new discovery.

Two problems still remain to be addressed:

1) The question regarding the causal determination of atomic processes; and
2) The question regarding the possibility of metaphysical constructions.

As to (1), it can also be phrased as follows. Is there causality at the atomic level? Considering our previous discussion, the answer is clear. If by causality we understand the relationship that lets the motion of ponderable particles depend on one another or on certain forces, then something of this sort is cannot be found among atoms, but not because there are no laws at all in this case, but rather only because we can no longer get by with the prospect of ponderable particles and the other familiar mental images [*Vorstellungen*] from the macroscopic domain. Or explicitly, there is no position where a mass point must be located with absolute precision, as mass points and positions no longer constitute the basic descriptive notions. The strict relation that on the large scale we call causality exists between certain mathematical quantities and no longer between objects of our perception (particle A and particle B). If we regard those particles as essential, then sure enough all the problems that quantum theory poses to a primitive-visualizable interpretation arise.

As to (2), following what has been discussed so far, there is no difficulty to promoting the newly discovered invariances to real things from now on, and to construct a metaphysics on this basis. For from (1), the argument of the unknowableness [*Unerkennbarkeit*] of a so-called external world also ceases to apply. If one is set on ponderable particles, then how the external world is to be construed is, sure enough, problematic. But if one uses the new concepts, there is no reason as to why we should not speak here likewise of an external world. Establishing this, however, is already a task for philosophy itself.

[5] The term is, linguistically speaking, a nonce-formation and is left untranslated. The term "Wimmelbewegung" (erratic motion) had been widely used in physics to refer to Brownian motion. Feyerabend's peculiar use with reference to Sommerfeld's atomic model is probably due to Johannes Stark, who employed it with a negative connotation to denote the electron motion as described in Sommerfeld's semi-classical atomic model. Cf. e.g. Sommerfeld's "doctrine of the erratic motion [*Wimmelbewegung*] of the electron in the atom" in Stark, J. (1930) "Die Kausalität im Verhalten des Elektrons" in: *Annalen der Physik*, 398(6), 681-699, p. 681; and "the dogmatists of the erratic motion [*Wimmelbewegung*] of the electron" in Stark, J. & Müller, W. (1941). *Jüdische und Deutsche Physik*. Leipzig: Heling-Verlag, p. 30. The compound term itself appears once in the expression "smeared erratic electron" [*verschmierten Wimmelelektron*] in v. Auwers, O. (1931). Review of Stark, J. (1931) *Fortschritte und Probleme der Atomforschung*. Leipzig: Barth in *Zeitschrift für technische Physik*, 12, 563-564, p. 564. (Thanks to Michael Eckert for providing information on the "German Physics" background of this terminology.)