Save the Phenomena

The Primacy of Unmediated Experience

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It seems that most adults who have completed their secondary education take the constructs of physics to be the material or magical "causes" of natural phenomena. Such an assumption is questionable, both epistemologically and pedagogically, and if we want to prevent this kind of error from continuing, it won't be enough to try to protect a few high school seniors. The only thing that will be effective in all types of schools is, from the outset, to follow a basic principle and adhere to it strictly: understanding needs grounding in the phenomena.

It is easy to see that only a very small percentage of physics students - five out of a hundred perhaps - have ever seen a planet in the sky or followed its course. I mean: the very thing, with the naked eye, outside. Nobody was there to point to the actual planet. This is a remarkable finding when one considers how the planets stood around the cradle of physics during its infancy in the sixteenth and seventeenth centuries.

Physics without an Ear for Sound

I'm convinced that the loss - or disappearance - of freely observed natural phenomena in the physics classrooms of our secondary schools and colleges is not merely a discarding of semblance and show. It implies that we disrespect our own foundations and those of natural science. In doing so we put our educational success at risk. We may lose our trustworthiness and credibility.

We risk getting caught in a common and old methodological temptation. Two hundred years ago, Pestalozzi - thirty-six years old at the time - wrote about it in a letter: "Schools bring judgments before people see and get to know things for themselves..." [i]

This can easily lead students to become prejudiced with the old argument about what has primacy: the things themselves (the first appearance, the phenomenal reality) or what we think *about* them, and *over and above* them, which means the mindscape of physics.

From early on the accusation was leveled against physics that it was out to spoil our faith in the senses. It is noticeable that this opinion is also not rare today. When one impresses on someone that "music is really nothing more than vibrations in the air, warmth as such only movement of molecules, color in fact nothing but electromagnetic wavelength," it will often happen that the person addressed will nod in agreement, albeit somberly.

Let's listen to a group of nine-year-old boys in the laboratory school of the University of Tübingen. They have a teacher who tells them little (he doesn't talk them into anything) and has taught them to talk with one another and to stick to the point, to say everything they think, but also to think about what they say. For hours they discuss why the sound of a distant jack hammer or of a drum lags so much behind the sighting of the movement. They check the skin of the drum with their eyes, fingers and tongues, they make their observations and say (according to the tape), "it hops and trembles, it trembles and tickles, it almost burns" (on the tongue). At last they conclude: arriving later is due to the air. Air "carries" the sound to us, and that takes time. And how does it "carry"? Their conclusion after a long conversation and experiments: when I beat against the drum skin, it wobbles and the air is pushed away. The air wobbles back and forth, and *that* air pushes the other air, and the air next to it, and so on. That way it wobbles through the air until it reaches my ear.

At a later point, these children will learn to record the wobbling at a place between drum and ear by means of a mechanical sound receiver. The results, then, will be something like the "air pressure curve." What have they, and we, gained through such a curve? The answer may be obvious, but strangely enough I have not found it in any textbook, namely: we have gained exactly what remains of the sound for someone who cannot hear.

Now if a teacher would say about this curve, "you see, the sound is in reality nothing but this vibration in the air," it would be absurd. Because why should the ear be singled out to be less relevant to record the reality of sound than the other, less appropriate senses? I'm not saying that teachers actually put such a "nothing but" expression in words. But what I miss is textbooks expressly denying this. The "nothing but" attitude seems to be in the air; it is between the lines. It is as if it were being learned along the way.

The teacher can, and should at this point, only pronounce the true state of affairs, namely that people in physics have *decided* to concern themselves only with the mechanical aspect, which is the air pressure curve. Hence "physical acoustics" only contains what remains of sound, and of music, for someone who is deaf.

And of course teachers should also make conscious what has prompted this decision to proceed in this way: air pressure can be measured, but the immediate experience of sound cannot. In this way the teacher can prepare the students for a fundamental insight, which is that physics is a *self-limiting* science, an intelligently renouncing science.

Above all, two things should be taken into consideration. In reducing ourselves to what can be measured, we cannot bypass the senses. We estimate and measure with hands and eyes, and the whole body; we measure *distance*, time *span*, and muscle *force*. Secondly, we must be clear about the fact that reducing the sound we hear to the air pressure curve is a one- way street. There is no way we can ever fully convey to someone who doesn't hear what a tone, a singing voice, or a gong sounds like. We can only give an indication in words.

When the teacher teaching acoustics allows the nine-year-olds to critically ponder the "wobbling" of the air in the way described above, and sticks to this way of teaching, he can keep them open for what they will later learn or read about modern physics, which is the following.

Physics is, according to the opinion of leading modern researchers, only one - albeit also the most powerful - of possible views of nature. It is not free from assumptions, but limits itself right from the start to what can be measured with yardstick, scale, and clock, insofar as we can bring the data thus measured into relationship with one another and coordinate them in mathematical structures. This results in a specific "picture of nature," or, as we could also say, a mindscape. [ii]

According to comparisons stemming from physicists themselves, physics gives us a picture of the surrounding sensory phenomena in the same way in which a map pictures a landscape, a score a symphony, or a shadow an object. In doing so, it gives a picture that is as sharp and correct as the shadow that a flowering tree throws on a wall. But of course the tree itself cannot want to be its shadow. Some of its structure and geometry remain, but color, smell, three-dimensionality, and the rustling of its leaves are missing.

The human being, who participates in nature after all, really cannot be expected to define the question about the "essence" of natural appearances by rational means, let alone find the answer. It is clear that we are only able to delineate the answer depending on one particular aspect chosen from a variety; and every aspect, physics included, imposes limitations as well. We circle around a mystery. Physics teaching should not favor an a priori impression that the core of this secret could ever be attained through physics. Bertrand Russell clearly states to what little degree physics can be ontology, can break through to the essence of things. He says, "What we know about the physical world... is much more abstract than was formerly supposed...Of the *laws* of these occurrences we know something - just so much as can be expressed in mathematical formulae - but of their *nature* we know nothing." [iii]

The Deep Unrest of Matter

We all experience the phenomenon of warmth when we sit in the sun. For warmth, the physics approach has found something very remarkable and worth seeing, namely that everything, be it stone, water, or air, has a constant, invisible, very fine trembling motion inside, which rises or falls with the temperature.

Ever since I saw with children this "Brownian movement" of small rutile crystals [in water] projected onto a screen through a dark-field microscope, I have been an advocate for disclosing this view of a reeling, starry sky to *all* children and to allow them to contemplate this sight in peace. This must be seen! It is hard to understand that all schools don't show this fundamental phenomenon to all children, instead of prematurely talking to them about atoms and electrons. Put them in front of the screen and say as little as possible. Then they will see something real.

Let us assume the ideal case that they don't "know" anything about "molecules" yet (or that one could first socratically talk them out of this belief). In that case the path would be open to a compelling approach to the notion of discontinuity and to the modern insight that the concepts won on a larger scale are not sufficient when they are transferred to a smaller scale. Here we have a first-class phenomenon that motivates and stimulates. Pressing questions arise: why are the dust particles in movement? Are they alive? No: simple chunks of soot, segments of crystal, or drops of fat will do the same, if only they are small enough. They are "*in* movement," so they don't move themselves, there is no "voluntary" movement; the particles do nothing themselves, they just join in the movement! What drives them? It can only be the water. But the water is completely quiet, isn't it?

Obviously that is not the case. One can hardly get around the hypothesis that we must imagine there to be a continuous pushing unrest in the deepest innards of the water (Philipp Lenard spoke of "tiny wiggling"); it is a very mysterious stirring, a micro-fever. It never stops, it is always there, and simply belongs to matter and warmth: it rises and falls with the temperature.

When we give students time and allow them the freedom to think for themselves (to which they are entitled), they will find this hypothesis of perpetual wiggling inappropriate. They would see it as a "perpetuum mobile," and a real one, one that causes friction! They would argue that such a wiggling could not last, that it would soon exhaust itself in friction (warming the water somewhat in the process)! This objection is compelling, and further forces us to come to a disconcerting conclusion. Water, the way we got to know it as children when we started to play with it; water, which ran through our fingers; water, which always became tranquil of its own accord, however wildly we had stirred it: this very water we were familiar with we now have to picture differently. Deep inside, in its tiniest dimensions, it must be very different from the way it is in a large dimension.

This seems not a bad entry into atomic theory to me. Combined with other conclusions that can be drawn from chemistry, it will be a fruitful starting point to build on later. This venture into atomism can stand as a digression. For my purpose here we don't need molecules at all yet. It is enough to register the discovery that there is a hidden, haphazard inner movement, the vehemence of which is bound to the degree of warmth.

Should we at this point resort to the "nothing but" philosophy again, saying: in reality warmth is nothing but inner movement? [iv] All we can say is this: increasing experience of warmth always goes together with a visible increase of inner unrest of the warm body, and the other way around. Or: the inner movement is what is left of warmth for a person who cannot feel warmth. Or, more clearly still: this is another case where physics opts for renunciation. It limits itself to "describing" warmth in terms which are measurable: movement.

With Brownian movement we approach a boundary. These reeling points of lights are the last optical reflection we can still glean from the innermost microscopic world of ordinary matter. According to the surprising insights of the past 50 years, when we penetrate even deeper, perceptibility is on principle not to be had when it comes to the processes that take place in the most minuscule spaces. Heisenberg states: "The atom is in essence not a material formation in space and time, but only, to a degree, a symbol, which, when introduced, makes natural laws assume a very simple form." [v] With this in mind, one cannot get rid of an uneasy feeling when one leafs through elementary textbooks. I am inclined to agree with another excellent quantum physicist, Walter Heitler from Zürich. He took pedagogical questions very seriously, remarking: "We do wrong when we want to teach young people something they can't possibly understand, or to misrepresent it in order to make it comprehensible ... I don't believe it is a good thing to talk about atomic physics and electrons in the upper elementary school. Every spatial representation of these formations is simply false." [6] It seems that schools, in their very striving to be up-to-date, simply are not so when they speak of atoms and electrons as if they were peas, without mentioning how people came to these ideas. In this way, schools no longer base themselves on phenomena.

Beyond Mechanism and Magic

The conception of electrons as hard things, only small ones, seems to be thoroughly entrenched, and this misunderstanding contributes heavily to the fact that so many laypeople believe in a hard, mechanical world underlying the phenomena, which are then viewed as "nothing but," with secondary effects that are "only subjective." We know that it is possible to give information that allows us to use products that we do not understand: driving a car, watching television, or using all manner of technical equipment; using mathematical formulae also belongs in this category. In many situations we cannot get around this. But a well-rounded education should not primarily be concerned with this form of "understanding." By understanding I mean: *standing on the phenomena*. In other words: experiencing how *physics - and this includes science as a whole - is and becomes possible*.

The use of axioms and deduction does not offer a way out. For when abstract concepts (in their genesis) have not arisen out of the phenomena, they will be *misunderstood*. They will be seen as objective findings rather than constructs that we have produced, and they will therefore be taken as either coarse material entities or as magical ones. Such entities are subsequently believed to be the ultimate causes behind everything that surrounds us - the ontological misunderstanding of physics.

I cannot go into all the ramifications of this subject here. I will only try to give some positive examples of how to make it possible to gain insight into the inner nature of matter, undreamt of before, staying completely in the realm of phenomena and without having to talk prematurely about molecules, atoms, and electrons. Let us start with the first subject, having to do once again with the "inner unrest" caused by the Brownian movement. This time not - as presented above - simply prepared by the teacher, but as a path (a "curriculum," if you will). I shall present a series that begins with direct experiences, a series set in motion by something strange:

Observe a stone, a polished metal surface, a still pond, some water in a glass, or the air of this room - they all make the impression of being completely at rest. When nothing and nobody interferes and there is no wind, no warmth, and no impact, you will see a dead, passive scene. With one exception. The water, given time, will surreptitiously disappear from the glass; it "evaporates," conquers the space, even though it does so slowly. Has the air absconded with it, or has it achieved this of its own accord? Does it want to flee? Well, we can take away the air. Let us put the glass with the water under a closed bell jar and pump the air out of the jar. We will experience a surprising eruption: the water, the cold water, begins to form big bubbles and boils away. So it obviously has only been waiting to get rid of the weight of the air, it wants to boil. When we take away the air pressure, we only assist what it wants to do of its own accord.

Now we know that water can also be brought to boil under the burden of the air pressure, in defiance of that pressure, namely by heating it up. Therefore we are allowed to say that it looks as if warmth merely supports water's inner compulsion to come to a boil. In summary, water, just by itself, has the tendency to become vapor.

This can stimulate us to look for similar processes. Sugar dissolves by itself in water. Several liquids layered over one another quietly mix by themselves over a period of days. We find the same thing with gases. Lastly, there also is the incredible diffusion of solid materials into one another. Gold, which has been pressed against lead for years, will gradually wander by itself in small amounts into the lead. And we will end this series of observations with the most familiar phenomenon: Air or vapor - all gases - are always ready to conquer any space open to them, either an empty one or one that is occupied by another gas. Their aggression is constant, and where they cannot escape, they press against the wall.

If, by way of culmination, we follow all this with a demonstration of the Brownian movement, we will perhaps notice how well it fits that the vehement rubbing and stirring makes all things warmer. The inner stirring can be reinforced from the outside.

This purely phenomenological sequence could show the following:

1. It is possible to give students insight into profound contexts, even if they are merely preparatory, without talking about mathematics or molecules.

2. Already ordinary matter will show a new side, one that is threatening. We can count ourselves lucky. Beware.

Demonstrations Bright and Weighty

This new side becomes even more compelling when augmented by a second insight that is also purely built on phenomena. The demonstration is artificial, but simple to set up. It involves not ordinary matter, as with the Brownian movement, but matter of a very threatening kind, namely radioactive materials. Look through an ordinary magnifying glass at a surface of material that has the special feature of giving off a tiny spark in the places where one scratches it with a needle. How it does that is a separate issue, which we do not need to understand here, because we only use it for the purpose of making a phenomenon appear.

Between the magnifying glass and the surface we hold a tiny bit of radium salt, applied to a thin wire on the side that faces the surface (the side away from the eye). The magnifying glass is adjusted to the surface. When it is pitch dark and your eyes are rested, preferably in the middle of the night, you will see a sight that is as unforgettable as the Brownian movement. No whirling stars this time, but stars that light up and disappear again in different places. It is a flickering starry sky. Now we have the possibility

- we are set up for that - to pull the radium salt a little bit away from the material while we are watching. We will then see how the stars diminish. Finally there are none left. And the other way around: if one brings the radium salt closer to the surface, the flickering will increase.

Allow me to insert something here. I do not speak out against using mathematics, nor against a moderate dose of atomic theory in high school. I have nothing against nurturing abstract intelligence, but I am against isolating it. I do not speak for a flight into the phenomena, but I do say that they should have priority. I am advocating *for* something, namely for experience, such as I have described here, being fundamental and remaining so. Of course quiet observation, reflection and dialogue take time. It is a remarkable thing that one often looks in vain for the preconditions for such learning in schools."Are those the atoms?" the over-informed child will ask. No, they are light flashes (scintillations). But one has the impression that this radium salt sprays from out of itself highly refined chaff that scratches the surface. It is not that we have really seen atoms, but we are close. As close as the tracks of a bird are to an actual bird that landed on the snow for a moment. This small and cheap peep-box for atoms is of course only a beginning step in the exploration of radioactivity. The next question from the child is likely to be, "Will the radium become less now?" Yes, it will. It won't go quickly, but it can be noticed after many years. Here one sees: *at this point* one cannot get around measuring and calculating anymore.

The examples brought here to illustrate making present and giving priority to the appearances lie close to the twilight zone of physics, where physical concepts can no longer be pictured. Here especially phenomena should be presented unencumbered by instruments wherever possible. They should make an impression that is hard to forget, no matter how much time is needed, and students should make these experiences before measurements are introduced.

Take the pendulum. It is certainly right to take as a starting point the memories every child has of being on swings. But a small brass ball on a thin short thread - is that really the same thing? For the scientists it is, but for the child it will diminish seriousness, because it smacks of dollhouse days.

Back in the early days of my teaching, I woke up to that one day. So one afternoon I dragged a chunk of rock as big as a soccer ball into the school, tied it to a thick rope and suspended it from the ceiling, which was about 16 feet high. The next day in the physics period I said nothing at all and only let the heavy pendulum swing into view from the side. How slowly it goes! Just looking at it has a calming effect. The demonstration gets the boys and girls out of their seats all by itself. Filled with respect, they crowd around the area where the pendulum swings. Nothing need be said. There is no need to arrange anything further in order for them to get a feel for the phenomenon; all that is needed is time, which schools are so rarely allowed to take. All heads follow the pendulum's path, back and forth, from left to right. At first there is the slow start, followed by the stormy rush through the midpoint - the fall is caught; on the other side comes the hesitant ascent until the point of return is reached. The rock doesn't get up as high as it was on the other side. Now the swing we were familiar with is objectified; we face it. It swings all by itself, almost effortlessly. No one needs to push; it is quite sure of itself. Just looking at it reminds us of moderation. This pendulum carries the measure of its swinging, its very slow swinging, within itself. Why does this long pendulum swing so slowly? At this point the realization dawns: here's when the number approaches, the law. The big pendulum evokes questions that don't arise when looking at the small, hasty one. The first question concerns the enigmatic highest point where the rock turns around. What happens at that moment; does it move there or does it not? Does it stop, or what? How long does that moment, where it doesn't move, last? Once this question has been seen, a conversation will start with uncertain outcome. The pupils will seek to understand what happens in the language they have at their disposal, not yet the language of physics. The teacher does not need to say anything. Only at the end he might summarize as follows: it has come to a standstill without duration, what physicists call a "moment." It is shorter than the blink of an eye, smaller than any moment, below number. Its duration is zero. A body stands there and yet it doesn't stand still; there *is* such a thing.

This introductory consideration does not preclude that we will come to the formula for pendulum movement. On the contrary, observation reveals the thing and allows it to speak, while at the same time allowing the students to be "with it." Haste spoils everything.

Physics Forgettable and Unforgettable

Quiet dialogue with both students and laypeople over the years shows that for many people a connection to natural phenomena is irrevocably torn. This begins early on in their schooling and is due to such factors as: entering too early and too hastily into the realm of quantitative teaching apparatus; merely copying technical terminology; only applying formulas; applying all-too tangible models that give rise to misunderstandings. As a result, students' perception is disturbed rather than enhanced, and their sensitivity for both phenomena and language is equally diminished.

The result is that many people do not like to remember the physics they had in school, and their learning disintegrates in no time.

It is worrisome to see how weak the retention is of what pupils learned in school about physics (close observation indicates that half a year after the completion of school is enough to let the knowledge dissipate), because teachers hardly perceive this and therefore do not believe it. If we look more closely at individual students we see an increase in cases where the expected knowledge has disintegrated, obscuring the phenomenon, rather than illuminating it. How else could it happen that about nine out of ten people witness month after month how the moon changes its luminous shape, yet believe all their lives that they learned in school (I suspect in a demonstration with a lamp, an apple and a nut, instead of looking at the phenomenon in the sky) that this is caused by the shadow of the earth. They have not once seen the way in which the sun is always positioned close to the narrow (therefore strongly darkened) sickle of the moon and not opposite it (the way it ought to be if the sun would project the shadow of the earth onto the moon.) There are many examples of this kind. Worse than these individual errors is the fact that many laypeople do not have any understanding of physics. A comparison presents itself:

In the same way in which a children's hospital, hygienic though it may be, cannot replace the mother in early childhood, in basic physics education the natural phenomenon cannot be represented by quantitative laboratory effects, however exact they may be, and this goes even more strongly for representing phenomena by means of models.

Physics will appear to the learner other than what it is - not a mindscape that limits but illuminates, overarching original nature and enriching it, but rather a subject that throws a shadow over an eerie *Natura denaturata* (denatured nature) and makes it desolate. [vii]

Allow me to close with a report by Marie Curie about the time when she and her husband Pierre Curie had discovered radium. She writes, "we observed with special joy how our radium-concentrated samples all glowed of their own accord. We would sometimes come back to the laboratory at night after dinner to have a look at our kingdom...Our precious products were spread out on tables and planks; from all sides one saw their dimly glowing outlines, and these lights, that seemed to float in the darkness, were always a new occasion for us to be moved and excited." [viii]

This is a condensed version of a longer essay written in German in 1975. It was first published in the journal Der mathematische und naturwissenschaftliche Unterricht *(1977, vol. 30 (3), pp. 129-137). It was re-published in the book* Naturphänomene sehen und verstehen *(by Martin Wagenschein and H. Chr. Berg, Stuttgart: Klett Verlag, 1980, pp. 90-104) and again in* Erinnerungen für Morgen *(by Martin Wagenschein, Weinheim: Beltz, 1983, pp. 135-153). The latter publication was used for this translation, and the subheadings were added by us. Translation by Jan Kees Saltet and Craig Holdrege.*

The complete essay is at: [natureinstitute.org/txt/mw/save_phenomena_full.htm.](natureinstitute.org/txt/mw/save_phenomena_full.htm)

Notes

[i]. Pestalozzi, J. H. (1949). *Sämtliche Briefe* vol. 3, p. 147. Berlin: de Gruyter. Pestalozzi wrote this letter to the tutor Peter Peterson in the spring of 1782 in Basel.

[ii]. Mehra, J., ed. (1973). The Physicist's Conception of Nature. Dordrecht: Reidel.

[iii]. Russell, Bertrand (1959). *The ABC of Relativity*, p. 142. New York: Mentor Books.

[iv]. Tyndall, J. (1867). *Die Wärme betrachtet als eine Art Bewegung*. Braunschweig: Vieweg. Francis Bacon, a contemporary of Galileo, had (like Democritus and Lucretius) a premonition of this hidden movement and subscribed unwittingly to the "nothing-but-philosophy." Tyndall quotes him as writing in 1620, "please note that we say ... that warmth is nothing but movement ... expansive, hampered movement that penetrates the particles."

[v]. Heisenberg, W. (1947). Wandlungen in den Grundlagen der Naturwissenschaften 7th edition, p. 97. Stuttgart: Hirzel.

[vi]. Heitler, W. (1973). "Vom Wesen der Quantenchemie," *Phys. Bl.* vol. 29, pp. 252 and 256.

[vii]. H. Kükelhaus launched a "Research Project for Organic Experience" in order to reawaken the destitute sense for phenomena. The project traveled to several German cities, stopping for a month at a time in each city, and met with great interest. See Kükelhaus, H. (1975). *Fassen, Fühlen, Bilden*. Köln. Compared to physics teachers, chemistry teachers have an even harder job staying long enough with the phenomenon and waiting sufficiently long before bringing atoms and atomic models. M. von Mackensen made a significant contribution recently in his article "Wie wirken atomistische Modellvorstellungen auf den (jungen) Menschen?" See: Buck, P. and M. von Mackensen (2006). *In Naturphänomene Leben*, 7th edition. Köln: Aulis Verlag. See also: von Mackensen, M. (1976). "Ein Entwicklungsproject zur Späteinführung der Modelle im Unterricht," in E. Fucke (ed.) *Berufliche und allgemeine Bildung in der Sekundarstufe II*. Stuttgart: Klett.

[viii]. Curie, M. (1961). "P. Curie, Wien 1950," *Phys. Bl.* vol. 17, p. 168.