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THE RADICAL CONSTRUCTIVIST VIEW OF SCIENCE

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Abstract
From the constructivist perspective, science cannot transcend the domain of experience. Scientific theories are seen as models that help to order and manage that domain. As the experiential field expands, models are replaced by others based on novel conceptual constructs. The paper suggests the substitution of 'viability' or 'functional fit' for the notions of Truth and objective representation of an experiencer-independent reality. This by-passes the sceptics' incontrovertible arguments against certain real-world knowledge and proposes the Piagetian conception of cognition as the function that generates ways and means for dealing with the world of experience.

Keywords: Abduction (Peirce), Abstractions, Experiential reality, Genetic Epistemology, Reflection, Scientific method, Scientific models, Theory of knowledge.

During the last decade of the century that has just come to a close, the term 'constructivism' became popular, and that has certain disadvantages. Constructivism cropped up in daily papers as well as in official publications of educational offices. What it stood for was presented as a panacea by some and as a pernicious heresy by others. Some of the propagators and many of the critics had not taken the trouble to consider what constructivism was intended to do. A clarification may therefore be appropriate. To begin with, it has to be pointed out that it does not purport to describe characteristics of the world but proposes a way of thinking that may be useful in dealing with a good many problems that face us today. This paper focuses specifically on the change of epistemological attitude the constructivist orientation might suggest to the practitioners of science and those who write about the results of that practice.

The ‘radical’ theory of knowing I have been working at for the last forty years is a developmental theory, based to a large extent on the work of Jean Piaget. He called his theory *Genetic Epistemology*, and his main purpose was the design of a model to show *how* children could possibly build up the knowledge they manifest as adults. He used the term ‘genetic’ in its 19th-century sense of ‘developmental’ and not in today’s biological sense of ‘depending on genes’. To most traditional philosophers, any such theory must be wrong, because it is based on what they call the ‘genetic fallacy’. True knowledge, to them, is a commodity supposed to exist as such, independent of experience, waiting to be discovered by a human knower. It is timeless and requires no development, except that the human share of it increases as exploration goes on.

The ‘Growth’ of knowledge

If philosophy of science is to give a plausible account of how scientists acquire what they consider to be knowledge, the conception of steady growth and expansion is clearly inadequate. The history of scientific ideas shows all too blatantly that there has been no over-all linear progression. The shifts from the geocentric to the heliocentric view of the planetary system, from Newton’s spatially stable to Einstein’s expanding universe, from the notion of rigid atomic determinism to that of a statistical basis and the principle of uncertainty, from an Earth with permanently arranged land masses to Wegener’s continental drift - and other upheavals could be mentioned - are incontrovertible signs that fundamental concepts were relinquished and replaced by ideas that were incompatible with earlier pictures of the world.

Karl Popper incorporated this observation in his ‘Conjectures and refutations’ and added as subtitle ‘The growth of scientific knowledge’ (Popper, 1968). He thought that this process was bound to lead science to a more and more adequate understanding of the real world. But he was unable to indicate how one could ever ascertain that the new conjectures were actually getting closer to such unquestionable ‘Truth’. This was one of the problems that had prompted Thomas Kuhn to try another approach.

One can certainly argue against details in Kuhn’s description of ‘scientific revolutions’ (1970), but no one can deny that every now and then the invention of wholly unforeseeable concepts has relegated previously held convictions to the growing scrap heap of explanatory theories. The image of the scientist gradually unveiling the mysteries of a world that is and forever remains what it is, does not seem appropriate.

The Notion of Scientific Models

One key to the puzzle was offered in the form of a metaphor proposed by Einstein:

> Physical concepts are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world. In our endeavor to understand reality we are somewhat like a man trying to understand the mechanism of a closed watch. He sees the face and the moving hands, even hears its ticking, but he has no way of opening the case. If he is ingenious he may form some picture of a mechanism which could be responsible for all the things he observes, but he may never be quite sure his picture is the only one which could explain his observations. He will never be able to compare his picture with the real mechanism and he cannot even imagine the possibility or the meaning of such a comparison.
>
> (Einstein & Infeld, 1967, p.31)

Later Einstein formulated the guiding principle:

> The object of all science, whether natural science or psychology, is to co-ordinate our experiences and to bring them into a logical order. (Einstein, 1955, p.1)

This principle forms the core of the constructivist epistemology and determines the constructivist view, not only of the results of scientific endeavor but also of all the ordinary knowledge we glean from everyday experience. Scientists struggle to bring their experiential world into rational order, and so do most other human beings, except that their notions of order and the methods to create it are less coherent and less explicit. Roughly speaking, the scientist’s task can be seen to consist of two alternating phases: the formation (invention) of conceptual structures and the attempt to demonstrate that experience can be fitted into these structures. Like the ingenious observer in Einstein’s metaphor, scientists invent theoretical models of mechanisms and test their viability in repeated and ‘controlled’ experiences that are called ‘experiments’. Non-scientists gather rules of thumb and attempt to apply them in their living practice. For both the actual purpose is not to obtain a ‘true’ picture of an observer-independent ‘reality’, but to provide tools for the management of experience.

Humberto Maturana has characterized the scientific method as a succession of four steps scientists enact when they intend to explain a specific phenomenon:

1 They define the conditions under which the phenomenon can be observed, in the hope that others will be able to confirm the observation.
2 They propose a hypothetical mechanism or model that could serve as explanation of how the phenomenon might arise.
3 From this mechanism they deduce a prediction concerning an event that has not yet been observed.
4 Then they proceed to define and generate the conditions under which the mechanism is expected to lead to the observation of the predicted event.[1]

Thanks to the frequent abuse of the word ‘phenomenon’ active scientists will hardly disagree with this analysis. Though it is not explicitly said, in this break-down the word is used in its proper sense; that is, it does not refer to things in an independent world, but to what observers isolate in their experience. Scientists are prompted to use their method of inquiry when they experience something which for one reason or another, they feel, requires an explanation. In the history of science, this happened quite often when observations were made that could not be explained by current theories. As Kuhn remarked, however, established theories usually manifest resistance against observed anomalies. Quite often an additional mechanism could be patched on to an existing model in order to cover a disturbing phenomenon. But such patchwork tends to become cumbersome and sooner or later more radical rethinking is unavoidable. This, of course raises the question *how* explanatory models (and the less ambitious rules of thumb) are created in the first place.

Patterns of Creative Thinking

I would propose two ways that seem different at first sight but on closer examination turn out to be somewhat related. The first is not unlike what infants do when, overwhelmed by amorphous experience, they begin to isolate pieces that appear to turn up repeatedly. Repetition and regularity are the elementary tools for the structuring of an experiential world.[2] Some recurrent things can be coupled to form relatively reliable correlations or, better still, causal connections. The infant, without conceptualizing these connections through reflection, tries to re-enact them because they produce an ‘interesting result’ (Piaget, 1937, chapter III). The adult scientist is able to reflect and abstract, and therefore can deliberately search for correlations among events and test them to find reliable patterns of the formP: if A (cause) - then B (effect). Where he can see a causal link, he formulates a rule and uses it as explanation, prediction, and, if possible, to control the sequence of experiences.

The other way of postulating a model is based on what Charles Peirce called ‘abduction’. He considered this a third form of inference and defined it in the pattern of a syllogism:

> The surprising fact C is observed;
> But if A were true, C would be a matter of course;
> Hence, there is reason to suspect that A is true.
> (Peirce, 1931-35; 5.189)

In Peirce’s formulation, ‘A’ stands for a hypothetical rule invented at the spur of the moment. To become viable as explanation and for making predictions, this new rule must be tested in the course of further experience - a kind of induction in reverse. If it turns out to be false, another rule has to be invented, until one is found that fits the experiential facts and can be considered a viable explanation.

This, of course, leaves the question of how such hypothetical rules are invented. Peter Medawar, by all accounts a serious scientist, thought that it required “a sanguine expectation of success and that ability to *imagine* what the truth might be which Shelley believed to be cognate with the poet’s imagination” (Medawar, 1984, pp.17-18). In other words, it is a procedure that has so far defied rational explanation. Most people who have thought about it seem to agree that analogy plays a role in it. But *seeing* an analogy is itself a rather mysterious process that is not unlike a minor abduction.

The reason why I said earlier that the two ways of constructing rules are not altogether dissimilar is precisely this: any coordination of experiences (or ‘data’) requires focusing on at least some of their particular characteristics. The choice of characteristics is usually very large, but the selection of those that are helpful in the quest for regularities and rules is not always random. Sometimes one has a hunch, and it is this form of intuition that distinguishes the productive scientist from the humdrum collectors of pointless data.

The Illusion of Objectivity

It is not surprising that concepts and their concatenation in causal chains that constitute theories, have to be modified and sometimes substituted when the range of experiences is enlarged and begins to incorporate areas that were hitherto not considered. The sudden development of shipping and sea voyages in the Renaissance, the invention of telescope, microscope, and x-rays, and many other technical achievements, generated experiences that exceeded the range of available theories and required fundamental conceptual changes.

In spite of these upheavals the tacit assumption persists that a theory that continues to fit experience and to yield satisfactory results must in some way reflect the structure of an independent reality. From the constructivist point of view, this illusion springs largely from the confusion of, on the one hand, the experiential reality composed of whatever concepts and knowledge are found to be viable in the practice of living and, on the other, a world supposed to exist, describable in itself, irrespective of any experiencer.

The way science is written about, and popularized, does much to reinforce this illusion, because it reiterates that the scientific method and its results are ‘objective’. This is an irresponsible play on the ambiguities of the words ‘object’, ‘objective’, and ‘objectivity’. The first is usually intended as an item isolated as part of experience; e.g. the chair you sit on, the keyboard in front of you, the hand that does the typing, the deep breath you have just taken. In short, any item of the furniture of someone’s experiential world can be called an object. In contrast, the philosophically minded also use the word for items to which they ascribe ‘existence’, which is to say, they posit them as entities supposed to be independent of anyone’s experience. In this vein, some mathematicians speak of numbers as ‘mathematical objects’ as though they existed without anyone generating them by reflection on an activity such as counting.

The other two words, ‘objective’ and ‘objectivity’, show a no less tricky ambiguity. On the one hand, they are intended to indicate the belief that the objects you have isolated in your experience are identical with those others have formed. From the constructivist point of view, this, too, is an illusion. It arises from the fact that we can recognize them and to a large extent agree on their description. None of this, however, requires an exact match of what we have individually abstracted from experience. Such commonality and communication shows no more than a relative compatibility of concepts in the situations in which we have had occasion to compare our individual uses of the particular words. Consequently, it would be preferable (and more accurate) if in all these cases we spoke of ‘intersubjective’ and ‘intersubjectivity’. This would preclude any fanciful flights into the realm of ontology. But in philosophical discourse, ‘objective’ and ‘objectivity’ are deliberately intended to imply direct knowledge of things as they are ‘in-themselves’, i.e. knowledge of items as they might be prior to being experienced. As Heinz von Foerster put it in conversation, ‘objectivity is the delusion that observations could be made without an observer’.

The Interpretation of Symbols

But what about measurements, you might say, or formal derivations - are they not objective? That this is an illusion was remarked a long time ago by Berkeley: “... to be of service to reckoning and mathematical demonstration is one thing, to set forth the nature of things is another” (Berkeley, 1721, §18). There is no measurement or computation without units. And to assume that units, be they discrete unitary objects or units of measurement, exist ready-made, prior to the segmenting and coordinating operations of an experiencer, is contingent on the metaphysical presupposition of an independent but knowable reality (cf. Glasersfeld, 1981). As for the objectivity (or certainty) of computations with symbols in either mathematics or logic, it pertains to the mental operations carried out and, as Berkeley remarked, not to the ontological nature of things.

The symbols used in mathematical computations designate operations that someone has to carry out. As Reuben Hersh put it: “Symbols are used as aids to thinking just as musical scores are used as aids to music. The music comes first, the score comes later” (Hersh, 1986, p.19). Even on the simplest level, for instance of 2+2=4, the symbol ‘2’ is meaningless for someone who has not abstracted the concept of ‘one’ from experiential items such as fingers, chocolates, or poker chips, and has then learned that sequences of these items can lead to the abstraction of compound units that are symbolized by ‘2’, ‘3’, ‘4’, etc. All other mathematical symbols similarly can be *understood* only by a thinker who knows and is able to execute the designated mental operations (cf. Steffe et al., 1983).

As for measurement, it, too, is contingent on the creation of units - units in the form of things to be counted or units of measurement to count ‘continuous’ items that are experienced without articulation of their own. In both cases it clearly is an active experiencer who creates the units. What is not so obvious, is that the discrete entities that are counted, as well as the continuous ones to which units of measurement are applied, are also an experiencer's creation.

The Segmentation of Experience

Nowhere have I found this better described than in the aphorisms on language and thought which Wilhelm von Humboldt wrote in 1795:

1. The essence of thinking consists in reflecting, i.e., in distinguishing what thinks from what is being thought.

2. In order to reflect, the mind must stand still for a moment in its progressive activity, must grasp as a unit what was just presented, and thus posit it as object against itself.

3. The mind then compares the units, of which several can be created in that way, and separates and connects them according to its needs. (Humboldt, 1907, p.581)[3]

The expression 'the progressive activity', I suggest, is to be interpreted as the mind's segmentation and coordination of the flow of the raw experiential material that Kant called 'the manifold' (*das Mannigfaltige*).

> The sensory perceptions (conscious empirical presentations) can only be called internal **appearances.** Not until understanding is added (and makes **order** in the manifold) does empirical knowledge, i.e., experience, arise from it.[4]
>
> (Kant, 1800, p.144; Kant's emphasis)

This is an amplification of Kant's earlier formulation "that reason can comprehend only what she herself has brought forth according to her design" (Kant, 1787,p.xvi).

Thus, what we ordinarily call 'experience' has already been ordered and structured into discrete 'things' by perceptual and conceptual operations which endless repetition has rendered unconscious, and by assimilation to more complex conceptual configurations that have been formed in past experience.

Piaget adopted Kant's general orientation, but disagreed with the notion of the 'a priori'. He replaced it with a developmental model of the child's construction of space, time, permanent objects, and causal relations among them (Piaget, 1937). The generation of these fundamental concepts begins with the construction of objects that appear recurrently in the child's experience.

Functional Fit instead of Representation

Apart from the focus on *how* the mind could generate the conceptual structure of knowledge, Piaget provided a reason why one should assume that it endeavors to do this. Note that Humboldt, in the 3rd aphorism I quoted, says that it "separates and connects [the units it has created] according to its needs", but does not specify what these needs might be and where they come from. Piaget's model provides an answer to these questions which, in my view, is his most important contribution to epistemology. He proposed that the purpose of cognition, since it could not be the discovery and representation of an independent world, should be considered a tool in the organism's adaptation to the world as it is experienced. Suggestions in this direction had been proposed earlier and and somewhat generically by William James (1880), Georg Simmel (1895), Alexander Bogdanov (1909), and Hans Vaihinger (1913). I do not know whether Piaget was aware of these earlier conjectures. In any case, he posited adaptation as the main goal of cognitive activity and extended the function of the concept from the domain of biological survival to that of the organism's internal mental equilibrium.

To recognize the full power of this position, one has to realize that adaptation is not an activity but the result of the elimination of all that is *not* adapted. Consequently, on the biological level, anything that manages to survive is 'adapted' to the environment in which it happens to find itself living. Once this is understood, it follows that what matters is not to *match* an ontic world, but to *fit* into the experiential one, in the sense of being able to avoid whatever obstacles or traps it might present. Taken out of the biological context and applied to cognition, this means that 'to know' is not to possess true representations of reality, but rather to possess ways and means of acting and thinking that allow one to attain the goals one happens to have chosen. To know, thus, is to have viable procedures or, as Maturana said "to operate adequately in an individual or cooperative situation" (1988, p.53).

This modification of the role of knowledge, from 'true' representation to *functional fit,* requires an enormous effort because it goes against a traditional belief that is at least three thousand years old. Some of the Pre-Socratics saw that this shift was possible, and the sceptics of all ages have reiterated that a true view of the real world could not be attained. But they were unable to specify a relation between knowledge and experience that could replace the conventional one of representation. The common sense view today is a peculiar hybrid. When people say they know such and such, it is presumed - and frequently taken for granted - that they are describing a state or an event of the real world. Yet most people are also aware of the fact that what we experience need not be objective (in either sense of the word). The great scientists of the 20th century have all stated in one way or another that they see themselves in the situation that Einstein described by his metaphor of the man and the watch. Yet, when they sit down to write generally accessible accounts of their achievements, they quickly repress that epistemological insight.

The Reluctance to Forego Ontology

Stephen Hawking, to give one example, writes in his Introduction to *A Brief History of Time* (1988, p.10)): “A physical theory is always provisional, in the sense that it is only a hypothesis: you can never prove it.” But throughout the following ten chapters there are many statements that reflect the belief that, in principle, physics can devise theories that describe the universe *as it is*.

Einstein implied the same belief in his famous dictum “God does not play dice”. This is a metaphysical assumption because it takes for granted that human reason can recognize and understand an observer-independent structure of the universe. Considering that, like other rational knowledge, scientific theories are derived from human experience and formulated in terms of human concepts, it seems no more than a pious hope to expect that these theories reflect anything that lies beyond the experiential interface.

The constructivist conclusion is unpopular. The most frequent objection takes the form of the accusation that constructivism *denies* reality. But this it does not. It only denies that we can rationally know a reality beyond our experience. Constructivism has no quarrel with the mystics who express their intuitions about a transcendent world in poetic metaphors which, of their nature, are not translatable into scientific language. From my point of view, the trouble is that most critics seem to be unwilling to accept the explicit, programmatic statement that constructivism is a theory of knowing, not of being. That a model of the construction of knowledge could be designed without making ontological claims about what is known, is apparently difficult to accept.

It is clear that fundamentalists, who claim to possess the one and only 'truth', cannot abide such a notion. And among the scientifically minded the reluctance may spring from the fact that to see the construction of theories as based on autonomous abductions and conceptual assimilation brings with it the realization that the responsibility for the gained knowledge lies with the constructor. It cannot be shifted to a pre-existing world. This deprives scientists of the comforting belief that what they do, can simply be justified as steps necessary for the growth of knowledge. The awareness that it is they who are responsible for their theoretical models and thus at least to some extent for actions based on them, might change the widely held belief that the direction of scientific research must not be fettered by ethical considerations.

Notes

1 Maturana presented this analysis at the Symposium in honor of Eric Lenneberg (Maturana, 1978, p.28) and continued to sharpen its formulation in later talks and publications from which I composed the concise form presented here.

2 From the constructivist perspective, the flow of experience does not present recurrent things as such, but repetition is created by the operations of 'assimilation'. A full account of assimilation is given in my 1995 book on Radical Constructivism.

3 The English translation is a slightly modified version of Nathan Rotenstreich (1974).

4 Kant used the German word *Vorstellung* in the first parenthesis of this quotation. It is usually translated as 'representation', which also covers the German word *Darstellung* (an image or replication of some original) and gives the misleading impression that the senses convey something that is already structured.

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