INTRINSIC VALUES IN SCIENCE

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Abstract

In the early 20th century, science was supposed to be "value free". In 1953 Richard Rudner claimed that "the scientist *qua* scientist makes value judgments", and later philosophers discussed the relations between science and values. From the 60's onward Michael Scriven and other authors came to the conclusion that non-moral values (intrinsic or epistemic values) are required to evaluate scientific works. This paper supports this general view. However, it stresses that there are several independent scientific values, corresponding to a multi-dimensional value space, and for this reason it is commonly impossible to compare the scientific worth of two different scientific contributions. Scientific values can be used to guide and to evaluate scientific research. However, the result is not a linear succession of better and better theories, but a proliferation of different theories and hypotheses, each of them fulfilling only a few *desiderata*.

Resumen

A principios del siglo XX se suponía que la ciencia era "libre de valores". En 1953 Richard Rudner concedió que "el científico como científico hace juicios de valor", y filósofos posteriores discutieron las relaciones entre la ciencia y los valores. A partir de los años 60, Michael Scriven y otros autores llegaron a la conclusión de que se requieren valores no-morales (valores científicos intrínsecos o epistémicos) para evaluar trabajos científicos. El presente artículo utiliza esta perspectiva general. Sin embargo, enfatiza que existen muchos valores científicos independientes, que corresponden a un espacio multidimensional de valores, y por esta razón es generalmente imposible comparar los valores científicos de dos contribuciones científicas distintas. Los valores científicos se pueden utilizar para dirigir y evaluar la investigación

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científica. Sin embargo, el resultado no es una sucesión lineal de teorías cada vez mejores sino una proliferación de teorías e hipótesis diversas, y cada una de ellas satisface sólo algunos *desiderata*.

Introduction

One hundred years ago, if a philosopher were asked whether values play any essential role in the scientific method, his answer would be a plain "No". The received view, around the last turn of the century, was that values might influence the choice of a scientific problem and the uses of science, but not scientific research itself. Values were regarded as intrinsically non-scientific –and that meant they had no significance for scientists as such[1]. Human values are not eternal, they depend on place and time, they are different in different cultures. Science, on the other side, seemed something shielded from social influences, it looked as though it was solid, immutable, universal. It was believed that science was grounded on well established facts. Everyone accepted that values could not be derived from facts, according to the so-called 'Hume's guillotine'[2]; therefore ethics and other axiological studies could never attain the same status as science.

A few years after the end of the second World War, a new view of the relations between science and values was presented by Richard Rudner, who at that time was working for the U. S. Navy Department. In his influential paper, he claimed that "value judgments are essentially involved in the procedures of science" (RUDNER 1953, p. 2) and therefore the scientist *qua* scientist makes value judgments. Rudner's thesis was grounded upon an analysis of the consequences of science –he discussed the relevance of *external* values in scientific decisions.

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1 Max Weber described science as "value free". According to him, science can only support hypothetical imperatives, such as "If you want B, then you ought to do A", not categorical imperatives: there is no science of ends as such.

2 'Hume's guillotine' is the statement that there is an unbridgeable gap separating fact from value and norm. Hume presented this view in his *Treatise of human nature*, book 3, part 1, end of section 1.

Rudner's paper was widely discussed. Richard Jeffrey and Isaac Levi criticized Rudner's arguments and rejected his conclusion (JEFFREY 1956, LEVI 1960). However, under the influence of Rudner's work, several philosophers came to discuss the relation between science and values. Although Rudner's work was deeply criticized, its ultimate result was the introduction of the concept of intrinsic scientific values[3]. It became gradually accepted that the scientific method can be described as a set of normative principles, and therefore the commitment to the "canons of inference" entails the acceptance of *some* values.

> Thus, the tenability of the value-neutrality thesis does not depend upon whether minimum probabilities for accepting or rejecting hypotheses are a function of values but upon whether the canons of inference require each scientist that he assigns the same minima as every other scientist (LEVI 1960, p. 567).[4]

That was a deep shift of the value-neutrality thesis. Recall that the scientific method was described as a special kind of *logic* or *calculus*, not as something of the same nature as ethics. However, around 1960

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3 Several authors arrived at similar ideas, independently of the stimulus provided by Rudner's paper. Michael Polanyi, for instance, referred to scientific values in his 1962 book and claimed that this kind of values was required in the evaluation of scientific works: "Though not definable in precise terms, scientific value can as a rule be reliably assessed. Its appraisal is required and depended upon every day in the process of advancing and disseminating science. Referees consulted by journals have to judge whether the scientific interest of a contribution would justify the expense of its publication. Other have to decide whether the award of a research grant is worth while. Scientists must be able to recognize what is manifestly trivial, just as what is manifestly false." (POLANYI 1962, p. 136)

4 Some years later, Levi's opinion was essentially the same: "When a person decides to engage in scientific activity, he perforce commits himself to certain values. He obligates himself never to accept contradictions as true, never to accept assertions from uncertified authorities, and, in general, to conform to certain principles governing when it is and when it is not legitimate to accept propositions on the basis of given evidence. A commitment to a scientific way of doing things is a value commitment which no reasonable interpretation of value neutrality can prohibit" (LEVI 1967, p. 119).

philosophers began to accept that the scientific method could be reduced to intrinsic scientific values[5].

The necessity of intrinsic scientific values

Michael Scriven presented some nice arguments in this direction. He pointed out that the same language and arguments related to values can be applied to different situations: "[...] "good" has no primary commitment to the moral use; it always serves the same function, that of indicating entities which score well on the relevant evaluation criteria, whatever they may be." (SCRIVEN 1967, p. 177). In particular, this applies to science:

> That science, whether pure or applied, necessarily involves *non*-moral value judgments follows immediately from an examination of the scientific procedure of evaluating hypotheses, explanations, theories, experimental designs, lab and field procedures. This is the heart and soul of science, and training the student to good standards and practices in these matters is widely held to be the most important aspect of his scientific apprenticeship (SCRIVEN 1967, p. 185).

This, again, is a shift in the understanding of scientific practice. According to Scriven, when we evaluate any scientific contribution (hypothesis, explanation, theory, and so forth) we are not stating that it is true or false. The assignment of *merit* to a scientific contribution is a value claim. It means that the scientific contribution is *good* according to some specific criteria.

In a second paper (SCRIVEN 1974), Scriven stressed that it clearly appears, from the context of scientific evaluations, that some methodological features are held to be valuable; and when those methodological descriptions are applied to scientific contributions, they are *ipso facto* endowed with merit[6]. Predicates such as "comprehensive", "prob-

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5 The phrase "intrinsic scientific values" does not mean, of course, values that can be justified by science itself, but values that apply to science as such.

6 "The connections between good/bad, ought/should, and right/wrong are very close,

able", "plausible", "confirmed", "simple", "general", "valid" and so on should be regarded as real-value predicates, implying worth or merit. Scriven concludes that "[...] science is *essentially* evaluative, would not be science if it could not make an thoroughly support a whole range of value judgments." (SCRIVEN 1974, p. 237).

Other authors reached similar conclusions. Carl Hempel was led to acknowledge that

> [...] epistemic valuation does enter into the *acceptance* of hypotheses or theories in this sense: the assertion that a given hypothesis H is *acceptable* in a given knowledge situation implies that the acceptance of H possesses a greater expectable epistemic value for science than does the acceptance of any rival hypothesis that may be under consideration (HEMPEL 1981, p. 398).

Hempel stressed that the epistemic value of a hypothesis cannot depend only on its truth value: "Science is interested not only in questions of truth and informational content, but also in the simplicity of the total system of accepted hypotheses, in its explanatory and predictive powers, and other factors, all of which a theory of inductive acceptance would have to take into account" (HEMPEL 1981, p. 399).

Scriven and the recent Hempel are some of the philosophers who accepted the axiological view of the scientific method. The aim of this paper, however, is not to write the history of this approach, but to discuss some aspects of this view[7].

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outside the moral domain as well as inside. The identification of superior *worth or merit* implies the identification of the *right and wrong* choices or actions, which are the ones a person *ought to* make or *should* do. If one *should* do X, if X is the *right* thing to do, then it surely follows definitionally that it's *better* to do X than something else, that doing X has greater *merit* than the alternatives, etc." (SCRIVEN 1974, p. 236).

7 I first presented a defense of an axiological approach to scientific method in MARTINS 1981 and MARTINS 1984. My PhD thesis (MARTINS 1987) contained a systematic development of this proposal. From that time onwards, this idea has guided much of my historical and epistemological investigation, such as MARTINS 1990, MARTINS 1993, MARTINS 1998.

What is the proper activity of scientists?

Nowadays, it is likely that most philosophers will agree that evaluating science presupposes intrinsic scientific (or epistemic) values. Notice that to say that evaluating a theory amounts to ascribe a value (in the axiological sense) to that theory is not a mere play with words. Of course, it is possible to say that the expression (4+8) ÷ 3 can be *evaluated* and that its *value* is 4, but those are mathematical values, with no merit or worth attached to them: there is no axiological connotation in this kind of "evaluation". On the other hand, when someone evaluates a theory, he is judging its worth or merit.

We might ask whether evaluating science is the proper activity of scientists as scientists. A scientific paper (or book) is the main result of a scientific research. A scientific paper can be described as a set of propositions together with tables, graphs, equations and other symbolic devices that can also be regarded as condensed propositions. In each scientific field, it is usually possible to distinguish between *scientific* (or first-level) *propositions* and *metascientific* (or second-level) *propositions*. Newton's gravitational law is a scientific proposition. Any proposition *about* Newton's gravitational law is a metascientific proposition.

What do we expect from scientists? Should they produce: (a) only scientific propositions; (b) only metascientific propositions; or (c) both? The second alternative seems unacceptable: if scientists are not expected to produce scientific propositions, who should produce them? On the other hand, we can easily imagine some kind of professional who would only produce metascientific propositions –philosophers of science, for instance.

There are several different metascientific disciplines: history of science, sociology of science, philosophy of science, and so on. A historian of science as such should produce only a specific kind of metascientific work. A physicist may include several historical propositions in a scientific paper, but we might say that when a physicist describes how he (or someone else) arrived to some scientific result, he is not acting as a scientist, but as a historian (usually as a bad historian, by the way – but that is another problem)[8].

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[8] A statement such as "I believe that *p* is true" or "I accept *p*" is not a scientific (first

In the same way, we might say that when a physicist evaluates a theory or hypothesis or any other piece of first-level science, he is not producing science –he is producing metascience. The study of values belongs to axiology, and axiology is a philosophical discipline. Therefore, when a scientist produces metascientific evaluations, he is acting as a philosopher of science.

If we accept this distinction, then we could claim that scientists as scientists do not *evaluate* scientific works –they *produce* scientific works. In that case, scientists as scientists do not make value judgments. Scriven foresaw this kind of objection, and replied:

> After all, the noblest task of physics has always been the critical scrutiny of the prevailing system of physics [...] after all, had Einstein or Schrödinger left the questions of the foundations of their subjects to philosophers of science? Should they have? Obviously not. The justification of basic positions in a science is a task for *both* the scientist and the philosopher (SCRIVEN 1974, p. 243).

I cannot agree that it is obvious that scientists should evaluate science. The production of a scientific contribution and the evaluation of a scientific contribution involve different kinds of expertise. Are musicians the best judges of music? Are politicians the best judges of politics? A philosopher may be able to evaluate a scientific work without being able to produce a scientific work. Why should the converse be true, for scientists? According to Scriven,

> [...] to be a scientist involves learning to distinguish between good theories and bad theories, between good experimental designs and bad ones. Someone who could not make such discriminations could not distinguish good science from bad science, science from non-science; and therefore could not be a scientist (SCRIVEN 1974, p. 238).

This is a nice argument. Scientists do not and should not produce a

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level) proposition. It is a metascientific historical description (specifically, a historical autobiographical psychological description).

random mixture of good and bad scientific contributions, to be selected later by philosophers. If they had no knowledge of scientific values, they could not try to do a good scientific work, they would be blind and would require external guidance to select their methodological strategies.

Let me present the argument for intrinsic values in scientific practice in a stronger form. When a scientist is producing science, he must choose some course of action. Now, an action can only be rationally justified (or vindicated, according to Feigl) by a set of purposes plus empirical knowledge about instrumental means that can lead to the intended aim. Purposes are associated to values. Therefore, any action, including the very procedure of producing science, presupposes the implicit or explicit use of scientific values[9].

Besides that, the final result –the scientific paper– cannot avoid the use of metascientific propositions. A scientific paper is not a heap of disconnected propositions, it is a web of interrelated propositions. If we recombine the propositions contained in a given paper, we have a new paper. If we forbid a scientist to add connectives such as 'hence', 'therefore', 'this contradicts', 'this conforms to', and so on, it might be impossible to write any interesting scientific paper.

Notice that there are several levels of metascience. In the strict sense, any proposition about a scientific proposition is metascientific. Let us suppose that *p* and *q* stand for purely scientific propositions. Statements such as '*p* is compatible with *q*', or '*p* can be derived from *q*', or '*p* confirms *q*' are, in the strict sense, metascientific propositions. That is the kind of metascientific proposition that must be present in any scientific theory or scientific argument, and therefore scientific theories and scientific arguments do contain metascientific propositions. Only a

9 It is curious that Hempel accepted that scientist act and that the justification of actions requires values, but he failed to notice that the basic scientific action is the production of science: "The action consists in including the given hypothesis into the corpus, K, of previously accepted hypotheses; and its purpose and potential value lies, not in solving any practical or technological problems, but in the increase of scientific knowledge. Since science aims at establishing true hypotheses, the addition of a hypothesis to the corpus of accepted hypotheses might plausibly be assigned a positive utility in case the hypothesis is true; otherwise a negative utility of the same numerical magnitude." (HEMPEL 1981, p. 397)

set of unrelated scientific propositions could be completely devoid of metascientific propositions. Logic connectives (and methodological or epistemological ones) transform a heap of disconnected propositions in a web of related propositions, and this web belongs to a different level.

When we establish a logical or methodological relation between two propositions –for instance, when we state that '*p* confirms *q*', we are thereby adding value to both *p* and *q*. Suppose that we cannot be sure whether *p* and *q* are true or false (that is what really happens in science). Suppose that *p* is a statement such as "whales have hair", and *q* is a statement such as "all mammals have hairs" (and suppose we accept that whales are mammals). The scientific value of *p* will increase if it is related to a more general statement such as *q*, and conversely, the scientific value of *q* also increases if we know a specific instance that confirms it[10].

If a scientist were forbidden to write any metascientific proposition, he could never *refer* to a scientific proposition[11] and could not state any *relation* between two scientific propositions[12]. I wonder what kind of science could be written in that way. Now, if the metascientific language (metascientific predicates and relations) is value loaded, the unavoidable metascientific propositions entering a scientific paper will entail value judgments.

Well, should all philosophers of science resign and leave to scientists the role of evaluating scientific works? Of course not. Scientists evaluate science in an "intuitive", non-systematic way. It is not their job to build a *theory of science*. That is the role of philosophers.

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10 In some cases, instead of positive value we might ascribe *negative value* to some logical connections. Suppose, for instance, that, instead of '*p* confirms *q*', we state '*p* is incompatible with *q*'. In that case, our confidence in *p* or *q* will decrease.

11 Not every reference to a scientific proposition ascribes value to it. Suppose we have two propositions *p* and *q*, and that we state that proposition *p* is different from proposition *q*. I cannot see how could this metascientific proposition change the scientific values of *p* and *q*.

12 Suppose that *p* is a scientific proposition (a hypothesis, an observational description, an experimental law, and so on). A proposition about *p* is not a scientific proposition, but a second level proposition (a metascientific proposition). If scientists can only propose scientific propositions, then a scientist *qua* scientist should not evaluate the probability of scientific propositions.

Which are the intrinsic values of science?

Let me call the attention of the reader to the specific concept of 'value' used here. Throughout the whole paper, when I refer that something has a (positive) value, I mean that this something is good or preferable to another thing, that it has some merit or worth. This kind of values is the object of axiology. In another completely different sense, we may say that the temperature of an object has also a value, and the density of a substance has a value, but a body with a higher temperature is not necessarily better than another with a lower temperature, and a body with a higher density is also not necessarily better than another with a lower density. Temperature, density and other scientific magnitudes can be ascribed numerical values, but that does not imply that they have values in the axiological sense. Mathematical values (numbers), values of scientific magnitudes and other similar 'values' are axiologically neutral.

Now, what about *logical* values? When a scientist or a philosopher states that some proposition is *false*, he is ascribing a (negative) value to that proposition, in the axiological sense. A true proposition is preferable to a false proposition, it has a higher epistemic value. Logical values are not axiologically neutral. Of course, in some contexts someone might prefer a false proposition to a true one, but that will be related to external (non epistemic) values.

Hither to no philosopher tried to present a full list of scientific values but there are scattered instances of such intrinsic values here and there. For instance:

> The 'ultimate values' lying behind assertions about the merit of a particular hypothesis are claims such as "Good hypotheses explain or predict or summarize more phenomena, or do it more simply, than bad ones." Even if we have to elaborate this under the pressure of counterexamples, it's a pretty close approximation to a definitional truth. (SCRIVEN 1974, p. 240).

This instance can be decomposed into several distinct values: it is scientifically good (a) to explain known phenomena; (b) to predict unknown phenomena; (c) to summarize a large scope of phenomena; (d) to provide simple explanations of phenomena; (e) it is scientifically better to explain (predict, summarize) a large number of phenomena than few phenomena.

We might add: (f) it is scientifically better to conflict with a small number of phenomena than with many phenomena; (g) it is scientifically good to frame hypotheses compatible with other accepted hypotheses and theories; (h) in the case of quantitative hypotheses, it is scientifically good to attain a close fit between predictions and experimental data.

Those values (together with a few others) can be used to evaluate proposed hypotheses[13], and to guide the search for new hypotheses. Similar rules apply to theories. However, science is not just a set of hypotheses and theories. Scientific papers contain lots of descriptions, classifications, measurements, definitions, and so on. What is a good scientific description? What is a good scientific classification? That is the kind of questions that should be answered by an axiological methodology of science. Philosophers of science, however, do seldom address those questions, nowadays. A lot of work would be required to sketch a general theory of intrinsic scientific values.

One or many scientific values?

If scientific values are to be used in practice to evaluate and guide research, it should be possible to identify whether a given value applies or not to each specific case. We cannot identify whether a given proposition is true or not. For that reason, although we do ascribe value to truth, it is not useful to include it among our methodological values. However, some philosophers do include truth among scientific values (HEMPEL 1981, p. 398; POLANYI 1962, pp. 135-8).

A *realist* philosopher might assume that it is possible, in principle, to frame a coherent scientific theory that corresponds to the external world, and that science is the search for that kind of theory. Truth is the ultimate value, although it cannot be identified. Instead of truth, however, we can use some identifiable properties, such as predicting power,

[13] There is a wide variety of hypotheses, some of them being much closer to observation than others. The set of rules presented here apply to higher-level hypotheses.

logical coherence, etc. These are not regarded as independent values, but derived or secondary values –clues that guide us to our goal.

Several old and new approaches to science assume that there is a one-dimensional continuum that leads from error (non-science) to perfect science. That is obviously the basic assumption behind all attempts to quantify the degree of confirmation or the probability or reliability of theories and hypotheses. However, the one-dimensional continuum is also required by other views of science, as I will attempt to show.

It is possible to assume that there is only one dimension of a given kind of values if and only if it is possible to replace or substitute any value of that kind by a suitable amount of another one. An analogy might elucidate this. Within nutritional theory, it is well known today that human beings need proteins, carbohydrates and fats, besides vitamins and minerals, to be healthy. A human being cannot be healthy –indeed he could not live– if his meals contained only proteins, for instance. One of those nutrients cannot replace the others.

Economic theory is founded upon one-dimensional values. Everything that can be discussed within economy can be replaced or substituted by money. If you believe that money can buy anything, you have an one-dimensional economic view of values. If you think that money cannot buy everything (that love, honor, dignity, authenticity, etc. are values that cannot be bought), then you require a higher-dimensional value theory.

Most philosophers of science accept that one of the aims of a theory of science is to provide criteria for the choice between scientific theories or hypotheses. Given two theories A and B, it is usually assumed that one of three exclusive alternatives applies: (a) either A is better than B, or (b) B is better than A, or (c) A and B have the same scientific value. These are the only alternatives if the scientific value is a one-dimensional continuum, similar to physical magnitudes such as temperature, time, mass. However, there are some higher-dimensional magnitudes that cannot be compared in that way. I will use an illustration from color theory.

Values and color theory

It is possible to describe all shades of gray, from the extreme white to black, as a one-dimensional continuum and to measure them by a single number. In a computer monitor, for instance, a black point (the darkest gray) is represented as a point of zero intensity, a white point (the brightest gray) is represented as a point of intensity 255, and there are 254 intermediate grays. Given two grays A and B, either A is brighter than B, or B is brighter than A, or A and B are equally bright.

The situation is completely different, however, when we describe colors. It is in general meaningless to state that a given blue is brighter or darker than a given red, for instance. That is because colors are three-dimensional objects, somehow similar to points in three-dimensional space[14].

Given two colors, it is sometimes possible to compare them and to decide that one of them is darker or lighter than the other (for instance, one blue can be darker than another blue of the same hue), but sometimes it is not possible to compare them. In the usual 24-bits notation used in computer art, it is possible to describe 16.777.216 colors, represented by a set of the three numbers (R, G, B), each of them varying from 0 to 255 (or, in hexadecimal notation, from 00 to FF). Black corresponds to (00, 00, 00) and the brightest white that can be exhibited on the computer monitor is (FF, FF, FF) or (255, 255, 255). Black is darker than any other color, full white is lighter than any other color. If we increase the intensity of all components in a color, we get a brighter color. If we increase one or two components and decrease two or one component, we get colors that cannot be compared as brighter or darker.

Using this analogy, we may compare the usual one-dimensional methodological analyses to discussions concerning white, black and

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14 I will use here the psychophysical theory of colors developped in the 19th century, that accepts that any color (as perceived by human beings) can be produced by a combination of suitable intensities of lights of three colors (red, green, blue). There are phenomena that cannot be explained in that way, but this theory is all that is needed to describe colors produced in a computer screen, because a color monitor has exactly three different phosphors, that emit respectively red, green and blue light, and all computer screen colors are combinations of those three basic colors. In this sense, colors are three-dimensional. In another sense, we might say that colors are associated to wavelengths, and that wavelengths form a one-dimensional continuum. But that is not relevant for the discussion of color perception.

gray. However, if we accept that there are different and independent types of scientific value, methodological analysis would be better compared to the description of a rich diversity of colors and hues.

When we describe personal values such as health, wisdom, wealth, beauty, fame, and so on, we are certainly dealing with a value space of several dimensions. Suppose that those values can vary independently of each other, and that for some specific person at time B all values except one are equal to those at time A, but one is higher: we can say that this person is better at time B than at A. But if one of those values higher and another is lower, we have situations that cannot be compared as better or worse. In the table below, B is better than A, C is better than A, but B is neither better nor worse than C.

	health	*wisdom*	*wealth*	*beauty*	*fame*
A	70	60	80	60	50
B	70	60	80	80	50
C	70	60	80	60	70

Also, when a philosophers refers to positive and negative values, he is assuming a one-dimensional continuum[15]. In mathematics, it is well known that complex numbers (that is, two-dimensional magnitudes) cannot be described as positive or negative. Only real numbers (or other one-dimensional magnitudes) can always be compared as greater than zero (positive) or smaller than zero (negative).

Any utilitarian approach to ethics or to scientific method (such as the one proposed by Brian Ellis[16]) also requires that values be regarded as one-dimensional, because in this case it is possible to make any mathematical sense of the concept of *maximization*.

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[15] "The desirability of undesirability attached to different possible outcomes are often assumed to be expressible numerically as positive or negative "utilities"." (HEMPEL 1981, p. 396)

[16] "The problem of induction is to show that our scientific inductive practices are more or less rational. To do this, I shall argue, we need a theory of rationality in which rationality is defined in terms of optimal strategies for maximizing epistemic value." (ELLIS 1988, p. 141).

Dimension of scientific values

Now let us return to intrinsic scientific values. Why should we suppose that all scientific evaluations can be reduced to one dimension, and that any pair of scientific contributions can be compared as better or worse?

If we assume, for instance, that there is a final, true theory of gravitation (the one theory chosen by God, or the one theory that corresponds to reality), we might associate (at least in principle) to each gravitational theory some epistemic "distance" from the final theory, and if only that distance is relevant, gravitational theories can be associated to points in a line, and they can be compared as closer to truth (better) or endowed with a greater scientific value.

However, it does seem that there are independent scientific values. We prefer simple to complex theories and hypotheses, but there is no reason to believe that the "true", "final" theory should be simple. We suppose that the "final" theory should be logically coherent, and that logical contradiction should be rejected. However, if we have two complementary theories, such as relativity and quantum mechanics, it may happen that they do not fit together, although each one separately is a powerful theory that is able to explain and predict many phenomena. We do not have logical coherence, but we do have explanatory power, and we prefer to use those incompatible theories than to reject them – at least as long as we do not have a better alternative.

Sometimes, in the history of science, there was a conflict between two theories that had different merits – for instance, Lorentz's ether theory and Einstein's relativity theory. Einstein's theory was simpler, but Lorentz's theory was the best, on other ways: it provided a causal explanation of relativistic phenomena. Philosophers have discussed why should Einstein's theory be preferred to Lorentz. In such cases, one might be trying to do something as impossible as comparing a red color to a blue one.

Hempel and other authors believed that there are some independent scientific values, but that they should be combined (as a weighted mean) in a single measure of the worth of each theory or hypothesis. Thomas Kuhn was one of the best known philosophers who supported this view[17]. Kuhn accepted that there are many independent scientific values, and that there is a fair unanimity about the desirable properties of scientific theories –such as accuracy, consistency, range, simplicity, fertility. Difficulties in comparing two different theories arise because each value may be assessed in different ways, and because there is no agreement concerning the weights to be ascribed to each value when value-conflicts arises –for instance, one theory might be simpler while the other might be more accurate. The significance assigned to each value will vary from person to person, that is, there will be a mixture between objective and subjective factors, or shared and individual criteria. In his analysis, Kuhn was concerned primarily with theory choice, and he concluded that the existence of individual or subjective criteria will explain the impossibility of reaching a general objective agreement concerning the best available theory at a given time.

Before the publication Kuhn's views, Scriven had assumed that weights had to be assigned, and he perceived the impossibility of justifying those weights:

> For the merit of a theory is not equivalent to the number of true predictions it generates, or the number of true explanations, or the extent of the simplification of the data it facilitates (even if there were some useful way to measure such quantities). It is a variably weighted combination of all of these, with the successful predictions, explanations, and simplifications themselves weighted according to importance, and the grand total offset by a weighted measure of the erroneous assertions or impressions. Even to talk in this imprecise way is misleading because it suggests that one could discover a precise formula by some kind of empirical or logical research. But there is no such formula, because the weights are themselves variable, being –rightly– affected by the relative success of different kinds of theories in the rest of science. (SCRIVEN 1967, p. 185.)

It is impossible to justify relative weights to be attributed to independent values. Any choice would be as conventional as a transforma-

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[17] This suggestion appeared in Kuhn (1970) and Kuhn (1977), chapter 13: "Objectivity, value judgment and theory choice".

tion of a color picture into a gray-scale one. This is an argument for the view that theory choice can have no epistemological grounds. However, this does not imply that we must be led to epistemological relativism. We can conclude that one should not attempt to provide a rational reconstruction of theory choice – but epistemology can use scientific values in other ways.

What is the use of scientific values?

Any normative theory of science can be rephrased as an axiological theory of science, since positive or negative norms (obligations or prohibitions) can be logically derived from value judgments. Although Popper, for instance, did not describe his theory of science as a theory of scientific values, we might rephrase his demarcation between science and non-science as a distinction between scientific good and scientific evil.

A normative theory of science usually prescribes that a scientist should act in some way and should not act in another way, or that he should produce scientific contributions that have some given qualities, and should not produce contributions that do not have those qualities. Instead of a difference between absolute scientific good and evil, other theories prescribe criteria of *relative* scientific good and evil, that would allow us to choose among competing theories or hypotheses.

All those attempts become problematic if we accept that there are several independent scientific values. In most cases, it will be impossible to compare two theories or hypotheses. In most cases, a given theory or hypothesis fits some criteria and therefore has some merit, but does not fit all criteria. Should it be accepted or rejected? Should a scientist refrain from publishing his work until he is able to fulfill all the scientific criteria, or should he publish his work once he is able to satisfy one or a few of the criteria? I think that he should publish his incomplete account. Although the scientific value of his work is not the highest, it is not null or negative. He is adding to science new information concerning an unknown being.

It is usually thought that the aim of epistemology should be to provide rules for the choice of hypotheses, theories, etc. The scientific community is regarded, in this case, as a group of censors that evaluate propositions and groups of propositions and allow or deny their inclusion in the scientific *corpus*. Does this theory deserve the honor of being included in the scientific *corpus*? That is the meaning of any demarcation criterion.

After all, why should we choose between alternative theories? That may seem a silly question. Life requires many choices: we choose to the best of our knowledge and possibilities a profession, a job, a wife or husband, a president, a football team. It seems natural that we should also try to choose the best theory, according to our knowledge. Well, but life is not always like that. I can have both a hot-dog and fries. I can have several different clothes. I can have several friends.

If science is regarded as the search for truth, and if we suppose that it is possible to distinguish true from false theories, then we have a good reason to choose the correct theory. No philosopher today accepts those premises, however.

If we accept the existence of several independent kinds of scientific values, corresponding to different criteria, each criterion can be independently satisfied or not by a given scientific work. None is obligatory, but each one is desirable: if fulfilled, it will associate a different merit to that scientific work. Instead of a linear scientific method, this view leads to divergent but equally valid contributions –each kind of work trying to fulfill different *desiderata*. Instead of a set of necessary and sufficient conditions for ascribing scientific value to a work, we may regard scientific values as independent non-necessary but sufficient conditions for ascribing scientific value to a piece of research. That is not what philosophers have been looking for, but it is enough to guide and evaluate scientific research.

Let me provide an illustration from the history of science. In the 17th century, Descartes proposed a general theory of the universe that explained several characteristics of the motion of the planets, and provided a mechanical explanation of gravity. Half a century later, Newton was able to provide a better quantitative explanation of the motion of planets, although he was unable to provide a general theory of the universe or to devise a mechanical explanation of gravitation, and could not explain why all planets turn around the Sun in the same sense (see MARTINS 1993). Which theory should be chosen? Perhaps the best answer is: choose both theories. Each approach had its own merits, corresponding to independent values. It would be possible to choose between them only if one of them fulfilled all the criteria met by the other, and in addition also fulfilled other criteria. But that was not the case. Instead of a choice, the best contribution to science might be to stimulate the development and improvement of both theories[18].

Final comments

The analysis of scientific values is far from complete. In this century, the concept of intrinsic scientific values was accepted and incorporated into epistemology. Any normative epistemology entails scientific values, and any scientific evaluation of scientific works requires the assumption of scientific values. The main role of scientists is to produce new scientific works, not to evaluate them, but even the development of scientific research requires actions that can only be justified by values, and scientific works cannot be completely devoid of methodological language that entails the use of scientific values. Hitherto no author has proposed a system of scientific values that can be applied to all scientific activities, but only to the development and evaluation of hypotheses and theories[19]. Some authors try to derive all scientific values from a single fundamental value (truth), but doubtless there are several independent scientific values, corresponding to a higher-dimensional value space. Those dimensions cannot be combined in any reasonable formula to produce a resultant, one-dimensional value. For that reason, it is usually impossible to compare the scientific values of two scientific contributions. This limitation prevents theory choice or hypothesis choice in most real-world situations. Scientific values can be used to guide scientific reasearch and to evaluate it, but the result is not a linear sucession of better and better theories, hypotheses, and so on. The

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[18] On this particular point, I agree with John Stuart Mill's defense of a variety of opinions, as recalled by Feyerabend (1980).

[19] According to Hugh Lacey, for instance, a criterion should be regarded as a cognitive value only if it is required to explain (by rational reconstruction) the theory choices made by scientists (LACEY 1977).

expected result is a proliferation of different theories and hypotheses, each of them fulfilling some *desiderata* but failling to incorporate all the merits of its rival proposals.

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