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Scientific Discovery and Its Rationality: Michael Polanyi's Epistemological Exposition

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Abstract
Scientific discovery is an important moment in scientific pursuit, but only a few philosophers of science appreciate this moment as a logical issue. Starting from his understanding that all thought contains components of which we are subsidiarily aware in focal content of thinking, Michael Polanyi puts out his thesis that scientific discovery cannot be justified by a series of strictly explicit operations but by merely invoking deeper forms of commitment in sighting the problem and the vision of reality. This article will delve into Polanyi's notion of scientific discovery in three sections: the first section is dealing with Polanyi's concept of heuristic philosophy which tones that discovery of problem is the primary requisite of a good scientist to vision reality, the second discusses the role of intellectual passions in scientific justification, and the third focuses on the ontological implication of scientific discovery that it guides us to comprehension of something real both tangible and intangible. The article concludes that since scientific discovery involves the creative and imaginative appeal to reality, its rationality must be counted on by its logical structure and personal experiences in scientific community.

Keywords Creativity · Emergence · Positivism · Scientific discovery · Tacit knowing

1 Introduction

Scientific discovery is one of the great themes in Michael Polanyi's writings. This topic is first introduced in *Science, Faith and Society* (1946) in which he seeks to discern the informal method for uncovering realities and is developed further in *Logic of Liberty* (1951) where the discovery is described as a result of the creative passions of the individual scientist.

However, only in *Personal Knowledge* (1958) and *The Tacit Dimension* (1966) is scientific discovery pictured more convincingly as the core of his philosophy of science. In *Personal Knowledge* Polanyi defends the idea of discovery as a personal, imaginative achievement, in confrontation with positivism (Sheppard 1999: 107). In his later book, *The Tacit Dimension*, he shows how the whole range of scientific activities becomes coherent in the

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light of his notion of tacit knowledge. In this book, and in some essays after the publication of *Personal Knowledge* (1958), discovery seems to be the distinctive element in Polanyi's epistemology.

One of the reasons for the attempts to clarify the issue of scientific discovery is the hope for its logic and method which has different character to the logic of scientific justification. It is Hanson (1972: 85–92) who distinguishes these two problems in the philosophy of science: the reasons for accepting a hypothesis and the reasons for suggesting hypothesis in the first place. The issue according to the above mentioned distinction is whether before having hit upon a hypothesis which succeeds in its predictions, one can have good reasons for anticipating that the hypothesis will be one of a particular kind.

Instead of following the objectivistic philosophy which establishes that the logical foundation of empirical knowledge must be defined by a kind of explicit rule, Polanyi is concerned with the existence of tacit inference in scientific discovery. In this new approach, he gives priority to the creative nascent period in the individual scientist in which he or she draws on quite different resources from those that follow the logical justification of proven achievements (Polanyi 1969: 156). He tells us that leaving out this creative moment, scientific verification will have no real meaning (Polanyi 1964a, b: 13–14).

This article deals with the process of scientific discovery as an informal method for uncovering realities. For this purpose, before discussing its scientific rationality, it will cover the problem of scientific discovery as a result of the creative passions of individual scientists. The philosophical relevance regarding scientific values and scientific realism will be taken as the reflective message of this article.

2 Towards a Heuristic Philosophy

Polanyi's philosophy of science comes as an "afterthought" (Polanyi 1983: 3) with regards to his career as a professional scientist. After finishing his Ph.D. in physical chemistry in 1917 at the University of Budapest and serving in the Ministry of Health in Hungary, Polanyi joined Reginald Herzog's Institute for Fiber Chemistry in 1920. Three years later, he became the director of the chemical kinetics research group in Fritz Haber's Institute for Physical Chemistry at the Kaiser Wilhelm Society in Berlin in 1923 and in 1929 was made a Life Member of the Institute. Polanyi resigned from the institute in 1933 when he left to take up permanent residence in England and became a professor in physical chemistry at the University of Manchester until 1948. In 1948 he exchanged his position in chemistry for a chair in social science that was specifically created for him at this university. Before turning to philosophy, he had seen his work on physical sciences published over 200 times (Nye 2017: 2327).

Polanyi's concept of scientific discovery is a response to positivism which develops the ideal of scientific detachment. By discussing significant scientific achievements such as the Copernican Revolution and Einstein's theory of special relativity, Polanyi defends the existence of tacit components which include the transmission of skill, interpretative framework, and creative imagination in scientific endeavour. He argues that scientific knowledge is a probable knowledge which incorporates the existence of anomalous data and random occurrences while nonetheless settling on general laws and a pattern of order. Although such knowledge relies increasingly on the operational principle of language, there is an unspecifiable and unarticulated knowledge among scientists that is not susceptible to language. It is clear for Polanyi, then, that discovery and justification of novel phenomena and

ideas requires breaking out of the language system and overcoming a logical gap. It is a heuristic process (Nye 2017: 3429).

Polanyi subscribes to Henri Poincaré who looks to the heuristic process as a personal choice which consists of preparation, incubation, illumination and verification. The stage of preparation is identified as the appreciation of a problem, illumination as the intelligent action to solve a problem, incubation as the curious persistence of heuristic tension through long periods of time during which the problem is not consciously entertained, and verification as the intention to know whether a discovery can be ascertained by our so-called reason (Polanyi 1964a: 121). Referring to these four stages of discovery, Polanyi remarks that all this process is creative in the sense that it is guided by the urge to make contact with reality (Polanyi 1964b: 34).

In particular, Hanson (1972: 44) calls our attention to the discovery of a problem as the primary requisite of a good scientist. Like many other philosophers from Plato to Popper (1979: 258), Polanyi proposes the idea that all true scientific research starts with a deep and promising problem. To see a problem that will lead to a great discovery is not just to see something hidden, but to see something of which the rest of humanity cannot have even an inkling (Polanyi 1969: 118). But, he also finds that there seems to be a paradox (Polanyi 1983: 22) involved in the very notion of a good problem, a paradox which has been pointed out by Plato in the *Meno* when he makes Meno ask: "But how will you look for something when you don't in the least know what it is? How on earth are you going to set up something you don't know as the object of your search?" (Plato 1968: 363).

Polanyi tells us that Plato puts forward the theory of recollection (Hanson 1972: 22) in explaining this paradox. In such a theory, knowledge is a priori in the sense that the deduction is independent of the life experience. With the myth of the soul—a powerful symbol of an entirely different world—Plato finds a way to remove any skeptical doubt about the possibility of inquiring into the truth. Plato's theory of recollection, however, exhibits our most optimistic mood, that man is in possession of absolute explicit knowledge. According to Polanyi, by putting forward a theory of recollection, Plato does not yet answer the question of Meno: how we can grope our way forward to make sense of our experience, so that we discover not only the error of our past prejudices but the possible truth of our conjectures. What matters most in the discussion of scientific discovery is the urgency of the problem, the possibility of knowing scientific problem.

Yet, in spite of the apparent contradiction claiming to be able to see a problem, Polanyi says that it is not that knowing a problem is impossible but "that if all knowledge is explicit, then we cannot know a problem or look for its solution" (Hanson 1972: 22). With this proposition, Polanyi proposes the thesis that knowing a problem is a kind of tacit knowledge, knowledge of which we cannot give a fully explicit account, but which nonetheless does exist. A problem needs to puzzle and to worry a scientist (Polanyi 1964a: 22). Most of the time, the scientist should think about the privileged problem and become engrossed with it. The problem is possessed by him and he is also possessed by the problem. As his inventive power is stimulated, he becomes more and more obsessed by the problem. Our knowledge of the problem is latent, tacit. It is an obsession.

Obsession towards the problem, then, is the mainspring of all inventive power. In "Problem Solving" Polanyi writes: "It is the unremitting preoccupation with a problem that lends to genius its proverbial capacity for taking infinitive pains. And the intensity of our preoccupation with a problem generates also our power for reorganizing our thoughts successfully, both during the hours of search and afterwards, during a period of rest" (Polanyi 1957: 98). But how can we concentrate our attention on something we

do not know? Or as George Polya puts it: how can we "look at the unknown and look at the end?" (Polya 1949: 23).

For Polanyi, "the problem is an intellectual desire" which postulates the existence of something that can satisfy that desire (Polanyi 1964a: 145). By directing our attention to a focus point in which we are subsidiarily aware of all the particulars that remind us of the unknown, we form a conception of it. To look at the unknown means that "we should look at the known data, not, however, in themselves, but as clues to the unknown; as pointers to it and parts of it" (Polanyi 1957: 98). We persistently concentrate our effort towards an understanding of the clues, their coherence in relation with one another, as well as with the problem. It is through the clues that we are given an access to the solution, i.e. that we have the focal awareness of the solution. The clues introduce us as the solver of the problem, the solution to which is still in the making. Hence, we are not totally blind to the solution; we have the eyes of anticipation to guide us as well as to sustain our hope.

The intimations we have of a problem and the possibility of a solution, then, are akin to the fruitfulness of any discovery that we come to accept as the solution of a problem. Somehow, we are able to appreciate the wealth of its as yet undiscovered consequences. We cannot formulate these intimations explicitly. This must have been the kind of foreknowledge the Copernicans had as they proceeded Newton in passionately affirming their heliocentric theory to be true. In our pursuit of discovery, "we are guided by sensing the presence of a hidden reality toward which our clues are pointing; and the discovery which terminates and satisfies this pursuit is still sustained by the same vision" (Polanyi 1983: 23–24).

Polanyi, therefore, maintains that "all knowledge is of the same kind as the knowledge of a problem" and concludes that "the paradigmatic case of scientific knowledge, in which all the faculties that are necessary for finding and holding scientific knowledge are fully developed, is the knowledge of an approaching discovery" (Polanyi 1983: 24–25). A good problem is that which is capable of giving something new and that which will lead to a contact with something hidden yet accessible. It could be considered a clue to discovering reality. Polanyi calls this moment a heuristic act because at this moment one acquires a new intellectual power which sets forth a vision of reality as the solution to the problem (Polanyi 1964a: 123). In this moment, a researcher crosses a logical gap between the known and the unknown, between the existing body of knowledge and the hidden aspects of reality he believes to be present.

For this reason, Polanyi identifies the scientist as a "pioneer mind" (Polanyi 1964a: 123) which reaches its own distinctive conclusions by crossing a logical gap deviating from the commonly accepted process of reasoning to achieve surprising results. The scientist has the capacity to make "contact with reality on an exceptionally wide range; seeing problems and reaching out to hidden possibilities for solving them, far beyond the anticipating powers of current conceptions" (Polanyi 1964a: 124). Discovery, then, is the personal achievement. It is an insight of reality: a reality which, being real, may yet reveal itself to future eyes in an indefinite range of unexpected manifestation.

This epistemological reflection gets its ethical resonance in *The Tacit Dimension*. Polanyi writes: the scientist's "vision of problem, his obsession with it, and his final leap to discovery are all filled from beginning to end with an obligation to an external objective" (Polanyi 1983: 77). In these intensely personal acts, there is no self-will. Originality is commanded at every stage by a sense of responsibility for advancing the growth of truth in men's minds. Although discovery is personal and solitary, it is not self-indulgent. The discoverer is imbued with a sense of responsibility for the pursuit of a hidden truth. His

knowing exercises a personal judgement in relating evidence to an external reality, and thus is undertaken with what Polanyi calls a 'universal intent' (Polanyi 1983: 78).

Polanyi does not say that our vision is always of a universal truth, but rather that it always has a 'universal intent' since, if we believe in the vision, we believe that it has made contact with reality, and we also believe that anyone else equipped as we ought to see what we see. With this valuation we can anticipate that our vision may be wrong and may be right; it is right only if it does make contact with reality and wrong only if it does not. But there are no irrefutable, explicit signs that say objectively that it has or has not made contact with reality. My conviction has the same structure as the conviction of others seeking to evaluate my vision.

3 Scientific Values

As far as discovery reveals new knowledge which is less than knowledge, for it is a guess, and more than knowledge, for it is a foreknowledge of things yet unknown, then, the question is how can we accept it as scientific? Or more clearly, why and how are discoveries suggested to be scientific?

Popper (1999: 31), who is not much interested in thought processes, argues that the initial stage, the act of conceiving or inventing a theory, is not the problem of philosophy. This issue tends to be relegated to psychological, sociological or historical causes and hence not to be regarded as part of the formal structure of science.

It is Charles Sanders Peirce who for the first time establishes the systematic effort to find a method of scientific discovery. According to Peirce, one can have good reasons for initially suggesting one kind of hypothesis, rather than another. The reasons may differ in type from those which lead one to accept a hypothesis once suggested, although this is not to deny that one's reasons for proposing a hypothesis initially may be identical with the reasons for later accepting it. Peirce calls his method 'abduction,' a term which he uses to designate the mental activity by which a hypothesis is formed. He also calls this activity 'retroduction' as a translation of Aristotle's word 'reduction.' In this method one starts with a case, and then devises a theory to explain it. The result is a probable hypothesis about that case. Abduction then is the process of forming an explanatory hypothesis, a new idea, or a guess which will be tested at in the verification stage (Peirce 1931: 31).

Peirce has his own contribution to the concept of scientific discovery as the logical moment in scientific pursuit. Looking at Polanyi's concept of scientific discovery from Peirce's perspective, Andy Sanders comments that Polanyi's notion of the logic of tacit inference, in connection with his notions of intuition and tacit integration, "allows us to draw a number of interesting and seldom noticed parallels with the Peircean notion of abduction" (Sanders 1988: 17). Abduction is an act of insight or of putting together; and this process resembles in kind a mental synthesis which Polanyi calls an act of integration. In such an act of integration scientific discovery reduces our focal awareness of observations to a subsidiary awareness of them, by shifting our attention from the observations to their theoretical coherence.

Both Peirce and Polanyi are anti-positivistic and contend that the progress that science has made must be attributed to the power of the human intellect fed with the facts of experience to introduce new ideas (Reilly 1970: 36). In such anti-positivistic spirit they refer to Whewell (1860: 254) who defends an idea that the progress of science depends upon the observation of the right fact by the minds furnished with appropriate ideas.

Polanyi's concept of scientific discovery, however, assumes more than the Peircian abduction. For Peirce abduction is the stage to find and formulate a hypothesis that will be proved in the stage of verification and which includes the stages of induction and deduction. Where in deduction the scientist deduces experiential predictions for a hypothesis, in induction the scientist evaluates the success of the prediction. Abduction, induction and deduction are, then, the pragmatic stages to achieve scientific truth. But, for Polanyi, scientific discovery is more than just a scientific hypothesis in such a pragmatic sense; it is not only a scientific knowledge that will be suggested to be proved but will be accepted in the context of scientific opinion in the scientific community. It includes the scientific progress from sighting the problem to the vision of reality. In short, it is the heuristic process in which the vision of reality can be seen in some sense as true scientific knowledge. But, how could it be valued?

As far as discovery reveals new knowledge which is less than knowledge, the scientific value of a discovery is made up of three coefficients: (1) certainty or accuracy (2) systematic relevance or profundity, and (3) the intrinsic interest of the subject matter (Polanyi 1964a: 135–136). These three criteria apply jointly, so that deficiency in one is largely compensated for by excellence in the others.

Certainty or accuracy means that science can be concerned with regularities. An event is regular if it is either reproducible or predictably recurrent. The reproducibility of a fact makes its observation exceptionally reliable, while its recurrence reveals that it forms part of a natural system (Polanyi 1964b: 30). Concerning the second criteria, i.e. systematic relevance, Polanyi explains that systematic interest can outweigh even the complete absence of regularity. It is because the systematic generality is an aspect of profundity in science and profundity is an indication of intimation that we are making a new, more extensive contact with reality (Polanyi 1964a: 136–137).

While certainty and systematic relevance combine in determining the scientific value of facts, the discoveries are also interesting in themselves. Polanyi writes: "Living animals are more interesting than their dead bodies; a dog more interesting than a fly; a man more interesting than a dog. In man himself, his moral life is more interesting than his digestion; and again, in human society the most interesting subjects are politics and history, which are the theatres of great moral decisions" (Polanyi 1964a: 138). The subjects that are most interesting in themselves do not lend themselves best to accurate observation and systematic study.

With these three coefficient elements of scientific value, Polanyi justifies the rational dimension of scientific discovery. This reminds me of a synthesis developed by Joseph D. Sneed wherein he talks about the logical structure of science. According to Sneed, all theoretical efforts have systematic character or logical reconstruction. As far as the scientific discovery is measured by certainty and systematic relevance, it is still a rational-systematic effort (Sneed 1979: xxiv). But this structural explanation needs a further clarification. Polanyi tends to say that a discovery should be valued as scientific by the satisfaction which it gives to the intellectual passions of scientists, which he defines as a scientific desire to understand, by the real implications which will be manifested in innumerable unforeseen ways in further research, by its fruitfulness in the sense that it could well be a source of truth, and by its gift to humanity which calls upon a scientist's commitment to defend it.

The value of scientific discovery, therefore, is determined by its fulfilment of scientific or intellectual passions. Polanyi traces two stages of the development of scientific discovery to explain it. In the first stage, it fulfils the discoverer's initial excitement. A theory, like that of relativity, continues to attract the continued interest of students and laymen by intimations of its beauty yet remains hidden to their understanding: a beauty which is

rediscovered every time. This is how scientific discovery satisfies the more personal intellectual passions. But, in the second stage, intellectual passions have a public dimension. Polanyi explains that scientific discovery continues to be valued as an intellectual triumph and accepted as a great truth. It terminates the problem from which it started, but it leaves behind a knowledge which gratifies a passion similar to that which sustained the craving for discovery. At this stage, "intellectual passions perpetuate themselves by their fulfilment" (Polanyi 1964a: 173). This perpetuation is largely due to the fact they are attached to an articulate framework or language. To interpret this moment, Prosch (1986: 99) identifies this moment of science as a part of human culture. Yielding to our intellectual passions, we desire to become more satisfying to ourselves, and to accept an obligation to educate ourselves by the standards which our passions have set to us. In this sense these passions are public, not private: the delight in cherishing something external to us, for its own sake.

Scientific discovery, then, is paradoxical. It includes the scientific method; but it is not overly strict because of the indeterminate character of scientific research in relation to reality and of the role accorded to the scientist's personal knowledge and capacity. Polanyi writes:

> Discovery differs from routine investigation. While a survey is conducted by explicitly established procedure, discovery cannot be arrived at by the diligent application of any explicitly established rules of inference. All existing rules of discovery are vague and ambiguous. While they offer useful hints any attempt to rely on them strictly could merely produce absurdities. The impossibility of formulating adequate rules for discoveries is expressed by ascribing originality to the discoverer (Polanyi 1961: 54).

With such remarks, especially that discovery describes "originality to the discoverer", Polanyi basically builds his theory of scientific discovery upon a personal heuristic approach. From the beginning, the scientist has but a vague and subtle intimation of its prospects. Yet these anticipations, which alert his solitary mind, are precious gifts of his originality. These anticipations contain a deepened sense of the nature of things and an awareness of the facts that might serve as clues to a suspected coherence in nature.

4 Appeal to Reality

In the context of a long debate between two opposing schools of thought called realism which "holds that the physical world exists independently of human thought and perception" and idealism which "claims that the physical world is in some way dependent on the conscious activity of humans", Immanuel Kant proposes his transcendental philosophy where phenomenal facts are not things in themselves but mere appearances. As far as Kant is right, the study of the appearances and the connections between them are an interaction not with nature but with one's own mind. Kant acknowledges that it sounds very strange and absurd that nature should direct itself according to our subjective ground of apperception, and should indeed depend upon it in respect of its conformity to law. But, as he writes in the *Critique of Pure Reason,* "when we consider that this nature is not a thing in itself but is merely an aggregate of appearances, so many representations of the mind, we shall not be surprised that we can discover it only in the radical faculty of all our knowledge, namely in transcendental apperception, in that unity on account of which alone it can be entitled the object of all possible experience—that is nature" (Kant 1952: A114). In such

a transcendental philosophy, Kant is of the opinion that it is the human intellect which invents and imposes its laws upon nature. The laws of nature are our own construction. They are man-made, genetically a priori.

This transcendental philosophy, however, denies the possibility of the consonance between the mind of the scientist and the workings of nature as the basis of human knowledge. Assuming the correspondence between the structure of comprehension and the structure of the comprehensive entity which is its object, Polanyi is adamant in his defence that, starting from the moment of problem-solving, scientific discovery is itself fraught with the further intimation of an indeterminate range, and "when we accept the discovery as true, we commit ourselves to a belief in all these as yet undisclosed, perhaps as yet unthinkable, consequences" (Polanyi 1983: 23).

With this vision of science, Polanyi claims himself a realist who contends that what scientists discover are aspects of reality. But, unlike traditional philosophical realism which insists that reality as such is independent of the knower and can be counted by an infinite number of mathematical formulae, Polanyi would like to say that reality has a link with the act of knowing. He argues that human beings have the power of knowing. However, since explicit rules in scientific knowledge can operate only by virtue of the tacit coefficient, which itself consists of some experiential elements of scientists participating in the search for rationality in the world, scientific propositions do not refer definitely to any observable fact but are describing something real which is expected "to reveal itself indeterminately in the future" (Polanyi 1964b: 10).

To clarify that all we know is a real thing which will 'reveal itself indeterminately in the future' Polanyi discusses the concept of emergence in biology. To rescue biology from reductionism, from being dissolved into merely physics and chemistry (Rosenberg and McShea 2008: 96), as described by Descartes, Polanyi, in resonance with the theory of evolution, announces that none of the biotic operations can be accounted for by the laws of physics and chemistry.

The context of this problem was the nineteenth century debate between mechanism—which "claims that living organisms are nothing other than very complex physico-chemical systems"—and vitalism—which "claims that certain characteristics of living systems cannot be explained by physical and chemical principle alone but have to be accounted by reference to vital forces" (Hempel 1966: 101). In dealing with this debate, Polanyi insists that living functions are determined at all stages by a combination of a mechanism with organismic regulation. As a physicist he acknowledges "a great deal of truth in the mechanical explanation of life" (Polanyi 1983: 42), but he also knows that the physico-chemical systems are not the only explanation, as he writes, "Hence a principle not present in the inanimate must come into operation when it gives birth to living things" (Polanyi 1983: 43). According to this logic, progress from one level to another in the stratified universe of living things cannot be done via reduction, or even by the continuation of the logic of one level with respect to the logic of the second above it, but rather by emergence. In such progress, the first emergence, by which life comes into existence, is the prototype of all subsequent stages of evolution, by which rising forms of life, with their higher principles, emerge into existence (Polanyi 1983: 49). The peak of it is man's moral sense because both the potentiality for obedience to higher demands and the capacity to feel reverence for men greater than oneself are aspects of the process of evolution (Polanyi 1983: 52).

With this concept of emergence and the concept of the stratification of the universe, Polanyi insists that the acts of scientific knowing have an ontological reference. He explains that realities, both tangible and intangible, have different manifestations. All of these things are real and accessible to human knowers. In this dialectical relationship

between knowledge and reality, Polanyi acknowledges on the one hand the independence of the real things which have "power for manifesting itself in yet unthought of ways in the future" (Polanyi 1983: 32) but on the other hand the real things are "waiting to be apprehended" (Polanyi 1964b: 35) by a scientist. Since the real is that which is expected to reveal itself indeterminately in the future, our knowledge of real things can never be fully explicit. In this light, it may appropriate to respect that scientific knowledge cannot be reached only by induction or protocol sentences as understood by the positivist. There is no specific method for making a good discovery because it is a creative process. In *The Tacit Dimension*, Polanyi says "The surmises of a working scientist are born of the imagination seeking discovery" (Polanyi 1983: 79). It does not mean that scientific method has no meaning in scientific pursuit. Rather, the proper use of scientific method always demands a touch of genius. Scientific discoveries do not usually arise from the analysis of a great mass of facts. The first stage is nearly always the outcome of reflective thought set in motion in a penetrating mind by the impact of a few very striking facts (Hull 1959: 192–193).

Science, then, is a creative, imaginative appeal to reality. As a creative process, it occurs in essentially two steps: the intuition and the imagination. The first step is the deliberate act of the imagination questing for the hidden reality suggested by the intuition's subsidiary awareness. The second step is in the spontaneous effort of the creative intuition groping toward integration. This creative process has certain content, that is, a vision of reality.

This creative process, however, needs valuation. It is generally accepted that the process of rationality is replaced by the principle of simplicity and fruitfulness and that its truth can be defined as a mere ordering of experience (Polanyi 1965: 8). Polanyi, however, says that all these categories presuppose a special sense known solely by scientists. As he writes, "Unless indeed the 'simple is tortured into meaning 'rational', and finally made to coincide with 'true'" (Polanyi 1965: 18). Scientific truthfulness is an appraisal of the bearing on reality of an idea and this bearing is dependent upon its tacit foundations. With this thesis, Polanyi criticizes that positivistic philosophy has no claim to truth. Based exclusively on empirical data, positivism tries to reduce the claim for truth to a moderate level. Polanyi points out that "scientific propositions do not claim to be true, but only to be likely" (Polanyi 1965: 17).

From this point of view, Polanyi tries to prove that personal appraisal is the last judge to our knowledge. To do this, he draws our attention to the paradox of the personal commitment: man's decisions are regarded as reflecting the highest degree of personal judgement precisely to the extent to which they appear most rational and in this sense most impersonal. This is the paradox of human knowing: on the one side it is personal, but on the other side it is universal. We say it is personal because the tacit component of knowing is the ultimate court of appeal for the meaning of our acts. But it is also universal because this tacit act of knowing stands under the imperious demand of universality. In science, Polanyi reminds us that this universality is one of intent, not fact, for there is no necessary connection between the truth of conclusions and their acceptance. In *The Tacit Dimension,* Polanyi formulates it in another way: "To claim validity for a statement merely declares that it ought to be accepted by all. The affirmation of scientific truth has an obligatory character which it shares with other valuations, declared universal by our own respect for them" (Polanyi 1983: 78).

From this centrality of personal knowledge and its sharing with other valuations grows Polanyi's vision of a society of explorers. It is a society of humans placed in the midst of potential discoveries, which offers innumerable problems. Polanyi assumes that although scientific discovery is a personal choice, scientific creativity is always based on the scientific belief of reality that has been experienced by the scientific community. It is in such a

society, therefore, that every scientist receives the calling to be an active center pursuing the truth with universal intent. The scientist is charged with his or her whole range of being to strive for integration, intelligence, and understanding. Acceptance of this calling is a choice that only each individual can make, but at the same time, it is a belief in the presence of a hidden reality that others can share.

5 Conclusion and Critical Notes

Polanyi's notion of scientific discovery as vision of reality has some epistemological implications. Firstly, it implies that science is a creative imaginative skill of knowing. As a skillful activity, the performance of scientific discovery differs from routine investigation. It is a creative act which involves imagination and intuition. For this this reason, it is not an exaggeration when Gelwick (1977) identifies Polanyi's philosophy of science as a heuristic philosophy: the main character of it is finding or discovering reality. Science finds its knowledge by a process in which personal powers are tacitly involved at every stage: from sighting a good problem, to holding the discovery as scientific. Science is a creative, imaginative appeal to reality.

This characterization has already been given by Whewell (1860: 41) in his concept of invention. In the same vein, Popper (2000: 33) refers to scientific hypothesis as conjectures. Indeed, Hempel in his effort to explain the structure of scientific inquiry stresses that there are no generally applicable rules of induction by which hypothesis or theories can be mechanically derived from empirical data. For him, the transition from data to theory requires creative imagination. Hempel calls this moment "happy guest" (Hempel 1966: 15).

Secondly, Polanyi's heuristic philosophy seems to say more about the content of scientific knowledge than the positivistic philosophy believed to be the status of scientific knowledge. When positivism identifies scientific inquiry as being guided by a passion for achieving absolutely impersonal knowledge, Polanyi defends the position that a discovery will be valued not only by certitude and systematic relevance, but also by the satisfaction which it gives to the intellectual passions of scientists. These passions are not merely a psychological by-product but have a rational function which contributes an indispensable element in science. This last remark contains an important reminder concerning the objectivity of science. While positivists emphasize that all hypotheses can be accepted into the body of scientific knowledge through critical scrutiny, Polanyi is of the opinion that they are not a result of mechanical procedure of induction but a personal achievement.

Thirdly, the concept of scientific discovery as a vision of reality implies that truth is the goal of scientific pursuits. This philosophical position has its relevance in response to the problem of relativism in the concept of the Kuhnian paradigm and Gadamerian prejudices. Polanyi acknowledges that both paradigm and prejudices are real backgrounds to our thoughts. They function as the social constitution of our mental life. But, paradigm and prejudices are not determinant factors in scientific knowledge. For Polanyi, a man who has learned to respect the truth will feel entitled to uphold the truth. "Responsibility and truth are in fact but two aspects of such a commitment: the act of judgement is its personal pole and the independent reality on which it bears is its external pole" (Polanyi 1983: 78). Every person may believe something different to be true, but as Polanyi explains, there is only one truth. The person who defines himself and his task as seeking universal truth should become a disciple of the truth. This truth is the surplus meaning of paradigm and

prejudices. An existing consensus, whether it is a scientific paradigm or the historical consciousness which we achieve, live and dwell in, is a clue to the truth.

Scientific discovery is a model of tacit knowing (Dua 2003: 245–247) which basically contends that "all thought dwells in its subsidiaries" (Polanyi 1983: x). In science, the subsidiaries include data in scientific investigation which functions as vectors pointing to theory and theories on which we dwell in shaping scientific knowledge (Polanyi 1969: 140). According to this from-to logic, scientific discovery depends on how deep the scientist dwells in the scientific problem, data, and theories which are anchored in the scientific community. This proposal, however, invites critical assessment, especially from Imre Lakatos. In his work *The Methodology of Scientific Programmes*, Lakatos judges Polanyi's proposal as intellectually elitist. He argues that if a large part of scientific knowledge involves a tacit dimension one can do science but there is no point in philosophising about it and the layman cannot be a judge in appraising scientific theories, because such a tacit dimension is shared and understood only by the elites (Lakatos and Musgrave 1978: 130).

It seems to be clear that Lakatos has touched the crucial weakness of Polanyi's theory of scientific knowledge because scientific method in Polanyi's view cannot be described as the application of explicit rules and procedures. Scientific discovery operates by selection, shaping, and assimilating clues, leaving to personal judgment an important role in deciding what should be concluded from them. It should be emphasized, however, that Polanyi is not saying that the process of scientific discovery does not involve adherence to particular rules and procedures. He emphasizes that these are only rules of arts, and the application of a rule must always rely ultimately upon acts which are not determined by rule, where application leaves room for the exercise of the personal judgment of the scientist. The process of scientific inquiry, then, is similar to any kind of skillful performance that involves the incorporation of elements that are largely unspecifiable.

Although scientific discovery is based on the personal pole, it is still a rational endeavour. To understand it, Wolfgang Stegmueller's analysis of scientific discovery can be applied to this case. Stegmueller tells us that until now logic is still appreciated as the only measure of scientific discovery. If this is the case, Popper was right when he says that there is no logic in scientific discovery, because there is no pure induction and deduction in scientific discovery. Yet logic is not the only criteria of scientific rationality. Besides logic, personal experiences in the history of science can be seen as another criteria of scientific rationality. Stegmueller argues that most scientists believe that all theories have an axiomatic Gestalt which can be mathematically and logically understood. But, he adds, these theories have no meaning if they are still on paper (Stegmueller 1975: 510). They must be seen as part of the historical experience of the scientists. In the logic of tacit knowing, logic and personal skill in using data, theories, and quasi-metaphysics are not only two components of scientific rationality but also the components of the subsidiaries on which we dwell in our scientific pursuits.

References

Dua, M. (2003). *Tacit knowing, Michael Polanyi's exposition of scientific knowledge*. Munchen: Herbert Utz Verlag.

Gelwick, R. (1977). *The way of discovery: An introduction to the thought of Michael Polanyi*. New York: Oxford University Press.

Hanson, N. R. (1972). *The patterns of discovery: An inquiry into the conceptual foundations of science*. New York: The Syndics of the Cambridge University Press.

Hempel, C. G. (1966). *Philosophy of natural science*. New York: Prentice Hall. Inc.

Hull, L. W. H. (1959). *History and philosophy of science*. New York: Longmans, Green and Co.

Kant, I. (1952). In R. Schmidt (Ed.), *Kritik der Reinen Vernunft*. A. 114. Hamburg: Verlag von Felix Meiner.

Lakatos, I., & Musgrave, A. (1978). *The methodology of scientific programmes*. Cambridge: Cambridge University Press.
Nye, M. J. (2017). Michael Polanyi: Science as personal knowledge and social practice. *Angewandte Chemie International Edition, 56*, 3427.
Peirce, C. S. (1931). *Collected papers*. Cambridge, MA.: Cambridge University Press.
Plato. (1968). In E. Hamilton & H. Chairns (Eds.), *Meno* (an English translation by W. K. C. Guthrie in *The Collected Dialogues of Plato*). Princeton: Princeton University Press.
Polanyi, M. (1957). Problem solving. *The British Journal for the Philosophy of Science, 8*, 89–103.
Polanyi, M. (1961). Note on Professor Grünbaum's Observation's 'the genesis of the special theory of relativity'. In F. Feigl & G. Maxwell (Eds.), *Current issues in the philosophy of science*. New York: Holt, Rinehart and Winston, Inc.
Polanyi, M. (1964a). *Personal knowledge: Towards a post-critical philosophy*. Chicago: The University of Chicago Press.
Polanyi, M. (1964b). *Science, faith and society*. Chicago: The University of Chicago.
Polanyi, M. (1965). *The logic of liberty: Reflections and rejoinders*. Chicago: The University of Chicago Press.
Polanyi, M. (1969). In M. Grene (Ed.), *Knowing and being*. Chicago: The University of Chicago Press.
Polanyi, M. (1983). *The tacit dimension*. Gloucester, MA: Peter Smith.
Polya, G. (1949). *Schule des Denkens: vom Lösen Mathematischer Problems* (a German translation of *How to Solve It* by E. Behnke). Bern: A. Franke AG Verlag.
Popper, K. (1979). *Objective knowledge: An Evolutionary Approach*. New York: Oxford University Press Inc.
Popper, K. (1999). *The Logic of Scientific Discovery* (an English translation of *Logik der Forschung*). London: Cornwall: TJ International Ltd.
Popper, K. (2000). *Conjectures and refutations, the growth of scientific knowledge*. New York: Routledge.
Prosch, H. (1986). *Michael Polanyi: A critical exposition*. Albany: State of University of New York Press.
Reilly, F. E. (1970). *Charles Peirce's theory of scientific method*. New York: Fordham University Press.
Rosenberg, A., & McShea, D. W. (2008). *Philosophy of biology, a contemporary introduction*. New York: Routledge.
Sanders, A. F. (1988). *Michael Polanyi's post-critical epistemology: A Reconstruction of some aspects of tacit knowing*. Amsterdam: Rodopi.
Sheppard, N. (1999). Michael Polanyi and the philosophy of science, the viewpoint of a practising scientist. *Appraisal, 2*(3), 107.
Sneed, J. D. (1979). *The logical structure of mathematical physics*. Boston: D. Reidel Publishing Company.
Stegmueller, W. (1975). *Hauptstroemungen der Gegenwarts-Philosophie* (Vol. 2). Stuttgart: Alfred Kroner Verlag.
Whewell, W. (1860). *Philosophy of discovery*. London: John W. Parker & Son.

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