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Hintikka's Interrogative Model and a Logic of Discovery and Justification

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Abstract: The relationship between discovery and justification is not clear. According to a standard twentieth-century opinion, in the philosophy of science these two are understood as separate problems: how to recognize and conceptualize the object of study and how to find the justification for the conceptualized belief. How to study the logic of discovery? What kind of logic might such a logic be? The basic observation is that discoveries do not take place in a vacuum. They have to be localized into scientific inquiry processes: a discovery is a discovery only in the context of a scientific inquiry process. To do this we use a systematic logico-philosophical model called the interrogative model of inquiry, which was developed by Jaakko Hintikka. The interrogative model of inquiry allows us to consider the scientific inquiry process as a strategic, goal-tracking process which gives justification for the discovery. The model allows us to formulate a systematic logic of scientific discovery and justification.

Keywords: *discovery, interrogative model of inquiry, justification, strategic questioning*

Introduction

A goal of scientific inquiry is to attain new knowledge. Moreover, in order to be the most humanly reliable way to acquire new knowledge, scientific inquiry has to be a *systematic* process. The systematicity needed has to be both institutional and theoretical. The institutional systematicity refers to organizations such as universities, research institutions, and funding institutions. All these are needed; scientific inquiry or scientific discussion is an actual human practice which takes place in the social reality. Theoretical systematicity refers to the organization of knowledge into theories and to methodological orientation. Scientific knowledge cannot be merely an agglomeration of separate pieces of information. To be scientific, knowledge must be expressed in a systematic way. Nevertheless, what is key is not how the expression is formulated, as this can be either in a linguistic or model theoretic way. Ideally, the formulation should be in the form of a theory (in a strict logical sense). The methodology of scientific inquiry refers to the study of the strategies of acquisition of new knowledge. The topic of the methodology is to characterize the general orientation of inquiry.

The structure of scientific theories has been studied extensively, especially by logical positivists. The theoretical background of the studies of logical positivists was the huge development of mathematical logic, as demonstrated in the monumental work *Principia Mathematica*, written by Russell and Whitehead. Mathematical logic was seen as a central tool in analyzing and expressing scientific theories. Mathematical logic made it possible to systematically study the linguistic structure of scientific theories, especially the axiomatization of theories, which was even recognized as the idealized form of a scientific theory by Aristotle. So, the development of mathematical logic meets the long-term desire of philosophers and scientists, or it seems to have been met. That is, "[t]he result was *the original version of the Received View*: A scientific theory is to be axiomatized in mathematical logic (first-order predicate calculus with equality). The terms of the logical axiomatization are to be divided into three: (1) logical and mathematical terms; (2) theoretical terms; and (3) observation terms which are given a phenomenal or observational interpretation" (Suppe, 1977, p. 12).

Purely observational statements were understood as verifiable with certainty through direct observation. The problem was how to verify general statements that are not verifiable by direct observation. "By means of characterizing the latter, logical positivists attempted to develop an inductive logic" (Suppe, 1977, p. 14). The inductive logic in the sense developed by logical positivism, as "inference from known to the unknown" (von Wright, 1965, p. 1), is something which differs from deductive reasoning. In particular, truth preservation characterizes deductive reasoning but not inductive reasoning. Hence, the problem of validity of inductive reasoning or justification of inductive inferences becomes a central problem. This problem of induction is known as *Hume's problem*. However, Hume's problem is not a proper problem in actual scientific research: "Hume's problem would play no role whatsoever in a serious theory of the scientific method and of the scientific process" (Hintikka, 1992, p. 25). That is, scientists undertaking actual inquiry do not worry about Hume's problem, instead they mainly worry about the search for new scientific results. So, "[i]t remains to examine the crucial first question. Surely the first order of business of any genuine theory of knowledge—the most important task both theoretically and practically—is how new information is acquired, not merely how previously obtained information can be evaluated." (Hintikka, 2007, p. 17)

Methodology

The 'genuine theory of knowledge' is closely related to the methodology of science, which studies the rationality of scientific inquiry in the most general sense. Methodological study includes both the general study of scientific inquiry and special case studies of scientific inquiry. Hence, in methodology we can find out that "there is much diversity of procedures and styles within science" (Feyerabend, 1975, p. 257). It seems quite plausible that science includes different kinds of procedures and styles; this happens between fields of sciences but also within a single field of science. Feyerabend has quite a strict procedure in mind when he speaks about methods in science: "The idea of a method that contains firm, unchanging, and absolutely binding principles for conducting the business of science meets considerable difficulty when confronted with the results of historical research." In fact, there are no methodological rules which are not broken during actual scientific inquiry. Thus, in the philosophy of science the problem referred to by Feyerabend is only a minor problem, as Feyerabend himself also says, because this practice "is not just a *fact* of the history of science. It is both reasonable and *absolutely necessary* for the growth of knowledge." (Feyerabend, 1975, p. 14.)

Marcello Pera (1981, p. 141) says that the "expression 'scientific method' is a *pollakôs legómenon*" which "contains at least three different explicanda" which are (i) a procedure, (ii) a set of rules of conduct, and (iii) a conceptual or operational technique. It is extremely important to separate these different meanings of the notion of method. All of them have a role in the scientific inquiry; however, it is important to map all the different meanings of the notion of method onto the landscape of inquiry. In this sense, Feyerabend's basic idea seems to be very interesting: what kind of method does he have in his mind? Or, more generally, what kind of method is a method of discovery?

In the philosophy of science, the central problem is not finding a single method, but rather characterizing a general methodological orientation of scientific inquiry, as the Peircean approach demonstrates. For example, general philosophical study explicates how the general demand of explicit argumentation and critical public discussion in scientific inquiry implies that the scientific method is also a *self-correcting* process (Niiniluoto, 1999). The other example, which is connected to the first, is the problem of scientific discovery. In this paper we consider the problem of discovery using Hintikka's interrogative model of inquiry. The other approach to the problem of discovery is Peircean abductive logic (Paavola, 2006). Peircean abduction is closely connected to the interrogative model (Hintikka, 2006; 2007).

According to the classical definition of knowledge, knowledge is a well-justified true belief. So, knowledge should be both true and justified, which are both very strong constraints which need to be further specified. In fact, inquiry starts from ignorance, and results in knowledge via the inquiry process. The inquiry process gives a justification for the knowledge; hence, it is a learning process which factually generates understanding about the object of inquiry (Hintikka, 2007; Hendricks & Hansen, 2014). This is closely connected to *Meno's problem* (Kelly, 1996). Etymologically, 'understanding' means standing between differences. How can the inquiry process provide understanding? Unfortunately there are no guarantees of success; there is no method which gives *a priori* guarantees that the intended goal will be achieved.

Scientific discovery is a process that involves a great deal of luck, and which occasionally takes place in science. Fortunately, minor discoveries are more conventional; hence, it is not enough just to have an idea; the idea has to be anchored to the intellectual framework of the inquiry. This anchoring gives a justification for the discovery, and, moreover, makes understanding possible (Hendricks & Hansen, 2014, pp. 18–19). That is, discovery is closely related to justification, which is connected to methodology. As a method-oriented learning process, the scientific inquiry process implies that the epistemic state of the inquirer will change (Hendricks, 2010). However, the inquirer, and his or her epistemic state, should be related to the corresponding scientific context. So, in the philosophy of science, the increase in objective scientific knowledge and subjective learning should be interconnected (Hintikka, 1982; 2007).

Therefore, we have to consider both first-person and third-person perspectives at the same "logical time" (Hendricks, 2007, pp. 33–34).

Discovery

The relationship between discovery and justification is not clear: according to a standard twentieth-century opinion, in the philosophy of science these two are understood as separate problems: how to recognize and conceptualize the object of study and how to find the justification for the conceptualized belief. The relationship between discovery and justification is worthy of closer study. The Reichenbachian dichotomy between the context of discovery and the context of justification separates the justification from the discovery (see, for example, Reichenbach, 1951). The Popperian interpretation in particular, which was an explication of the mainstream interpretation in the early 20th century, says that of discovery, "the act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible of it" (Popper, 1959, p. 31). This interpretation sounds acceptable if we suppose the Popperian approach, but the historical or factual justification for it is not very strong. The experimental method in particular can be seen as a stepwise knowledge construction; in experimental science inquirers are making knowledge in a literary sense (Sintonen, 1994; Hintikka, 1988). Hence, experimental science seems to falsify the method of error elimination à la Popper. Moreover, scientific inquiry can be more generally conceptualized as proper inquiry (Hintikka, 1999).

The distinction between the contexts of discovery and justification becomes a very interesting task to analyze. If we accept the hypothetico-deductive model, then the separation of the contexts becomes very natural. However, the role of the hypothetico-deductive model should be reviewed (Laudan, 1981; Hintikka, 2007). If we take a look at the whole inquiry process, then the logic of discovery becomes a smooth target of logico-philosophical study:

> In the philosophy of science, the slogan is still sometimes heard that there is no logic of discovery. By this, philosophers mean either that discovery is not subject to logical analysis the way test or confirmation is or that it is impossible to give explicit rules for discovery. […] Regarding the first point, one may conceive of assessment as binary discovery (h vs. neg-h), so that there may be a difference in degree of complication between the two cases,

> but no difference relevant to the applicability of logical analysis. Regarding the second point, it will be shown that discovery can be demonstrably easier than assessment, at least so far as finding a correct answer is concerned. (Kelly, 1996, p. 13)

There are several consequences of the separation of the contexts. Especially as the Popperian example shows that the notion of discovery will be connected to the notions of creativity and (ir)rationality, which makes the analysis of the notion of discovery extremely messy. In fact, the incoherence of the conceptual basis can be identified in several approaches, as the following quotation demonstrates:

> Russ Hanson, who thought the logic of discovery was a good thing, advocated the method of abduction, which was a method for the evaluation, not the discovery, of hypothesis. Hans Reichenbach, who was notorious for insisting that the 'context of discovery' is of no philosophical significance, was a proponent of straight rule of induction, a technique for the discovery of natural regularities if ever there was one. Not to be slighted here is Karl Popper, who wrote a book called *The Logic of Scientific Discovery*, which denies the existence of any referent for its title. (Laudan, 1981, p. 181)

It is an obvious fact that in science discoveries take place. But it is not obvious how discoveries are generated or what kind of processes bring them about. There are several historical case studies of scientific discoveries; Kuhn, for example, has carried out several scholarly case studies of discoveries in the history of scientific discoveries. However, there is also a need for a philosophical study of the topic. That is, to study philosophically how scientific discoveries are or, rather, might be generated, that is, to study the logic of discovery. What kind of logic might such a logic be? (Hintikka, 2007; Laudan, 1981)

The logic of discovery is not a simple topic; the identification of a discovery separates different approaches. The Popperian approach identifies discovery as an irrational accidental mental jump (Popper, 1959, p. 31). The Kordingian approach identifies discoveries as the whole process of inquiry, including the justification of the idea (Kording, 1978). A mediating approach is to identify a scientific discovery such that the mere idea is not good enough, but to be a discovery the full justification is not assumed. To give a more specific context for this, Laudan (1981, p. 182) formulates the mediating notion, the *context of pursuit*. Obviously, the difference in identification of the notion of discovery causes differences in the analysis of the scientific discovery. The distinction between the contexts of discovery and justification is particularly understandable if we assume the Popperian approach, but what if we do not?

The Popperian approach identifies discovery with the irrational, accidental mental jump, which Laudan (1981) calls "the *eureka* moment". Hence the discovery—by definition—looks like an irrational step which excludes logical analysis. On the contrary, Laudan (1981, p. 182) says that he sees "the logic of discovery as a set of rules or principles according to which new discoveries can be *generated*". The analysis of such a logic of discovery, or "self-corrective logics of discovery" (Laudan, 1981, p. 187), should include both the context of discovery and justification which can be connected to the idea of scientific method as a self-correcting process. The notion of strategy becomes a central notion when looking at scientific inquiry as goal directing process. However, the possibility of giving the justification independently of the idea generating process was already recognized in the 1830s and 1840s. In fact, this was a foundational idea behind the hypothetico-deductive model of science (Laudan, 1981, ch. 11).

The interpretation of creativity and discovery as irrational steps makes the study of the logic of discovery extremely complex—or even impossible. In any case such an interpretation interconnects the notions with several different but interrelated problems. Simon (1977) characterizes the problematic behind the logic of discovery clearly:

> The subject of scientific discovery (and creativity generally) has always been surrounded by dense mists of romanticism and downright know-nothingism. Even well-informed persons, who do not believe that the stork brings new babies, and who are prepared to accept empirical account of biological creation, sometimes balk at naturalistic explanations of the creation of ideas. It appears that the human mind is the final citadel of vitalism. (Simon, 1977, p. 266)

The notion of strategy allows us to subject scientific discovery to logico-conceptual analysis. This has been done by Hintikka in his interrogative model of inquiry. Moreover, the strategic view interconnects different approaches of scientific discovery. Especially, Peirce's abductive logic can be understood as such a strategic approach which interconnects the Peircean approach and Hintikka's approach. (Hintikka, 1998; Paavola, 2004)

Popper (1979, p. 176) argued that discoveries do not take place in a vacuum; discoveries are solutions to puzzling problems a scientist has. However, these kinds of observations localize the discovery into scientific inquiry processes: a discovery is a discovery only in the context of a scientific inquiry process. However, scientific inquiry is not blind problem solving but rather a strategic process of problem solving in which the search for new additional information and logical inferences play together, generating new solutions to the problems—generating new knowledge and discoveries. The central problem of the logic of discovery is to characterize this kind of strategic process explicitly. The logic of discovery can be explicitly formulated (Hintikka, 2007; Hendricks, 2001; 2010).

Interrogative model of inquiry

In order to give a logic of discovery, we have to specify a conceptually clear model of the knowledge acquisition process. Moreover, to be realistic the model should be empirically adequate. The first step of inquiry is to realize the ignorance. As the Socrates's example demonstrates, it is not so easy to recognize one's own ignorance: if someone makes the ignorance of other people visible, they are not pleased and become angry. After the recognition of the ignorance, the most natural way to obtain the necessary knowledge is to pose questions to some suitable sources of information. Usually there is no single source of information which could directly change the ignorance into knowledge: there must be some knowledge construction. In science this questioning and knowledge construction must be methodical or strategic. The strategic questioning together with the evaluation of sources of information become central factors in the methodology of science. Socrates was a great strategic questioner, and the Socratic method of questioning is documented by Plato in his dialogues. Aristotle further developed Plato's theory of questioning: he developed not only a general theory of questioning strategy (*Topica*) but also a general theory of knowledge construction. In particular, *syllogistic* may been seen as a strategy theory for answering questions which do not assume any additional information (Hintikka, 2007).

Recognizing ignorance in a fruitful way is not an easy task (Kahneman, 2011). Questioning is not just asking questions but also evaluating the knowledge one has, and it is related to the questioner's state of knowledge. The questioner is asking information so that he or she is able to construct the knowledge required, and the answer which allows the questioner to do this is called the complete answer. Besides evaluation of the knowledge, evaluation of the sources of information is a central problem to assess. The questioner needs to have some, essentially methodological, knowledge about the information that the different sources are capable of giving as answers to questions. There is no reason to assume that for each problem there could be a source of information which could give a complete answer. In fact, such an assumption is closely related to failure, known as begging the question (Hintikka, 2007).

The role of methodology is to build up a general methodological orientation which tells us how to construct the knowledge needed to solve the problems using the information from the sources. Thus, the questioning process is a multilevel one in which big, goal-identifying questions orientate the whole process, and minor operative questions are used in searching for additional information for the process. A systematic logico-philosophical approach, in which knowledge acquisition is based on questioning, is known as the *interrogative model of inquiry* (Hintikka, 2007; Jung, 1996). The first systematic approach to the interrogative model is the Socratic questioning method, and Aristotle formulated the logical foundation of the interrogative model in his philosophy. The idea is to develop a general theory of knowledge acquisition which is fundamental methodological information (Hendricks & Hansen, 2014, p. 18). That is, the logical character of questions and answers and the strategies of different kinds of questioning processes (Hintikka, Halonen & Mutanen, 2002).

The questioning can be seen as a simple request for information or a strategic means in an inquiry process. The former may be common in our colloquial language but in a scientific context it has a secondary meaning. In science, a question should be understood as a methodological or strategic tool that gives us a general methodological map of scientific inquiry and knowledge acquisition more generally. Kant emphasizes the strategic role of questioning: he says that reason may not be "in the character of a pupil who listens to everything that the teacher chooses to say, but of an appointed judge who compels the witness to answer questions which he has himself formulated" (quoted in Sintonen, 1994, pp. 127–128). The fundamental idea is the active and constructive role of human reason in knowledge acquisition. This has been demonstrated in the experimental method, which makes it a very interesting field in which to apply the interrogative model. (Sintonen, 2006; Mutanen, 2014)

As a general constructive method of knowledge acquisition, the questioning method can be seen as a general method of discovery. Hence a systematic 'logic of discovery' becomes quite a natural and effective logic. In fact, the underlying logic is basically ordinary first-order logic. Moreover, if the sources of information are known to be reliable, then the logic generated becomes truth preserving. This can be called the pure logic of discovery. This leads to a strange conclusion that the logic of discovery is easier to establish than the logic of justification (Hintikka, Halonen & Mutanen, 2002). Hence, the prejudice that we have fundamental logico-conceptual difficulties in formulating a logic of discovery is indeed just a prejudice.

The actuality of logic of discovery does not mean that there is some mechanical discovery machine, with Reichenbach (1951, p. 231) arguing for the impossibility of such a discovery machine. Feyerabend (1975, p. 121) argues for the irrationality of discovery which is related to his '"mechanical" notion of scientific rule. In fact, hope for such a discovery machine would be unreasonable. A well-known logical fact is that in elementary geometry, which is a complete theory in that there is a decision procedure for elementary geometry, there is no computable method to generate effective constructions (Hintikka & Remes, 1974). Hintikka and Remes (1974, especially ch. IX) argues that the geometrical analysis was a methodological model for early experimental science.

The truth table method gives a decision method for propositional logic. The method of distributive normal forms can be seen as a generalization of the truth table method. However, the method of distributive normal forms does not offer a decision method because "there is no recursive way of finding out which constituents are inconsistent, although there is a very natural mechanical way of weeding out certain trivially inconsistent ones" (Hintikka, 1973, p. 21). Still, distributive normal forms have a lot of logical and philosophical interest. The method of distributive normal forms, just as the truth table method, gives a method which interconnects the proof theoretical and model theoretical approaches in logic (Hintikka, 1987b). Hintikka further developed this interconnection in his interrogative model of inquiry, in which the notions of surface and depth information (Hintikka, 1973) and the theory of questions and answers (Hintikka, 1976) are interconnected with the logico-philosophical ideas developed by him earlier (Hintikka, 1987b; 2006).

The interrogative model is closely connected to Peircean abductive reasoning. Peirce anticipated the game-theoretical approach, which is one fundament in Hintikka's interrogative model (Hintikka, 2006). Moreover, according to Peirce (1955, p. 151), abductive inference is related to interrogation, with both the interrogative model and Peircean abduction strongly emphasizing strategies of reasoning (Hintikka, 2007; Paavola, 2004). So, the interrogative model allows us to study the strategies of scientific inquiry and strategies of scientific discovery explicitly: "The interest that the interrogative model has is largely due to the fact that it enables us to study strategies of scientific inquiry and even strategies of discovery in the form of strategies of question selection" (Hintikka & Harris, 1988).

Reliability

The questioning method is a very natural method for acquiring information. However, to be understood as a method of inquiry it must be systematized, and the systematization is carried out within the interrogative model of inquiry. The systematization allows us to consider the reliability of the method. That is, how well and in which contexts the process achieves the intended result. In this, the interrogative model of inquiry is a parallel approach to some other formal approaches to knowledge acquisition, such as computational epistemology (Kelly, 1996), the formal learning theory (Gold, 1967; Osherson, Stob & Weinstein, 1986) and the modal operator theory (Hendricks, 2007).

The central aspect of the interrogative model is the strategic questioning process. The questioning process, of course, must be explicated, which implies that a similar questioning process can be repeated. The repetition of a similar questioning process is not just intended to get the same bit of information once again, which would be epistemically worthless. The value of the repetition is not (only) pedagogical; of course, it has pedagogical value, but this is not the only value, and not even the main value. The value of questioning processes for the interrogative model is mainly methodological. The methodological value comes from evaluating the whole questioning process but, even more importantly, evaluating the sources of information. Through the repetition of the same questioning, the inquirer is testing the sources of information: "if Nature's answers to repetitions of one and the same question are independent of one another, the best way for the Inquirer to ascertain that Nature's answer is veridical may be to repeat the same question and hope for the same answer" (Hintikka, 1992, p. 25).

More generally, the inquirer should formulate different kinds of reasoning processes which take place if the questions are changed. Changes to the questioning process lead to changes in the reasoning processes, hence the questions can be seen as a symptom of the independence of the reasoning process from another reasoning process. So, the questions indicate how the process depends on the source of information and on which sources it depends (Hintikka, 1992; 2007). Hence, we have it that a given piece of evidence of the conclusion "is essentially an issue related to how the evidence or information has been collected—thus an agenda concern, or a methodological concern, of how inquiry methods for knowledge acquisition interact" (Hendricks, 2010, p. 287).

By asking the same question, or the same sequence of questions, twice, the questions are probabilistically dependent. However, to have epistemic value these similar questions, or sequences of questions, have to be formulated independently. This is achieved if, for example, the questions (experiments) are carried out in different laboratories. Such a repetition of the similar questions increases the reliability of the sources of information if the answers are the same. As a result, the independent repetition of the similar sequences of questions is of central importance in making the method reliable (Hintikka, 2007).

The different kinds of questions, or sequences of questions, for example, refer to different kinds of experiments. Here the notion of 'different kind' refers to probabilistic independence. If different kinds of questions are used to imply the same conclusion, then the situation differs from the repetition of the same question. In order to understand why the inquirer uses different kinds of questions to reach one and the same conclusion, we have to look at the whole process more closely. According to the interrogative model, the inquirer is trying to infer the conclusion by using normal truth-preserving logic together with some amount of additional information. To evaluate the support the information gives to the conclusion, let us take a look at the following example (more precisely, see Hintikka, 1987a). Let the inquirer perform two different questioning processes: Q_1 and Q_2, which give information I_1 and I_2, respectively. Now if $I_1 = I_2$ then information I_2 does not provide any new information, assuming that we already have information I_1, or the conditional probability of I_2 assuming I_1 is large. This explains why the repetition of the same question only increases the reliability of the sources of information (if the questioning processes are independent). However, if the questioning processes are probabilistically independent, then the conditional probability becomes smaller, which increases the informational value of information I_2 assuming that the inquirer already has information I_1. This can be generalized: to increase the probability of the conclusion, the new additional information should be probabilistically independent on the information already given. The more improbable the new information is relative to information already given, the more reliable it makes the conclusion. (Hintikka, 1987a, p. 434)

Here it is essential to evaluate the reliability of the forthcoming information and its support for the final conclusion. In essence, the reasoning is reliable since the underlying logic is truth preserving. However, the reliability of the forthcoming information and its support for the final conclusion has to be considered carefully. If some reasonable doubt remains about the reliability of the forthcoming information, it is possible to use the bracketing rule, which indicates the unreliable statements in the argument (Hintikka, Halonen & Mutanen, 2002).

In fact, this contradicts the basic assumption of the hypothetico-deductive model of inquiry, which is expressed by Popper (1979, p. 81) as follows: "The method of science is the method of bold conjectures and ingenious and severe attempts to refute them." The basic idea of the interrogative model is to construct knowledge in a strategic process. The bold conjectures to which Popper refers are called hypotheses. Newton explained that "whatever is not deduced from phenomena is to be called hypothesis" (Suppe, 1977, p. 347). The interrogative model makes the idea behind Newton's characterization more understandable by demonstrating what kind of logic Newtonian constructive logic might be. In the interrogative model there is no need for bold conjectures, but rather a need for excellence in reasoning (Hintikka & Bachman, 1991). The interrogative model is not a trial and refutation method but a constructive method of reasoning (Hintikka, 2007; Sintonen, 1994).

To get a better grasp of this, let us take a look at what happens in usual induction. Let an inquirer have some conclusion, say C, which he or she is intending to justify, that is, he or she is trying to find evidence which makes the intended conclusion probable. At a given moment all the evidence the inquirer has is the sequence $e_1, e_2, \ldots, e_n$. This gives some amount of support to the intended conclusion, say $P(C/ e_1, e_2, \ldots, e_n)$. The inquirer carries out one more experiment which gives new evidence e_{n+1}. Now the support given by evidence $e_1, e_2, \ldots, e_n, e_{n+1}$ is $P(C/ e_1, e_2, \ldots, e_n, e_{n+1})$. Here the support depends only on the numerical difference in the evidence statements e_i. The repetition of an experiment seems to be particularly worthless—it just gives the same result: $e_1, e_2, \ldots, e_n = e_1, e_2, \ldots, e_n, e_n$. (Hintikka, 1987a)

This shows why the same experiment does not increase the reliability of the conclusion. However, this does not explain the role of the similar experiment or the increase in reliability of the properly new piece of information (von Wright, 1965). In general, in the usual inductive logic only the numerical difference is meaningful. We know that the inquirers are carrying out similar experiments all the time. The interrogative model allows us to show that the repeated experiment increases the reliability of the sources of information if the answers are the same. Moreover, the interrogative model allows us to evaluate the increase in the reliability of the reasoning process. (Hintikka, 2007)

As a constructive logic, the interrogative model explains scientific reasoning quite well. The constructive role of experiments in constructing knowledge becomes particularly evident. The role of different kinds of experiments is explained. For example, as we have seen, the experiments which give information which is probabilistically independent bring essentially new information into the inquiry process. This is closely related to the notion of consilience of scientific inference, which refers to the opinion that the support for a theory is the stronger, the more different kinds of evidence it has. Whewell expressed this as follows: "The Consilience of Inductions takes place when an Induction, obtained from one class of facts, coincides with an Induction, obtained from another class. This Consilience is a test of the truth of the Theory in which it occurs." (quoted in Hintikka, 1987a, p. 433)

We have seen that the reason the interrogative model explains the consilience is that according to the interrogative model, the increase in the probability is not based, as in ordinary induction, on the numerical difference between the evidence; the reason is the independence of the lines of reasoning.

> The probabilistic independence of q_1 and q_2 means in practice that the experiment in question has no systematic bias. It is also for the purpose of eliminating such a systematic bias that the Inquirer may want to construct a parallel but converging argument instead of repeating the same one. The strength of the converging arguments then does not lie primarily in their number or variety; it lies in their independence and their dissimilarity. In induction, there is safety in numbers. In interrogative arguments, there is safety in independence. (Hintikka, 1987a, p. 437)

The interrogative model gives quite a natural characterization to the reasoning in experimental science. The logic of experiments closely follows the lines of reasoning of the model (Hintikka, 2007, pp. 119–121). The logic of human sciences, such as hermeneutics, seems to be different. The tradition of hermeneutics does not suffer from "objectivistic illusion" (Rorty, 1980, p. 381). The fundamental idea behind hermeneutics is human understanding, this means, for example, that in education we cultivate students, or "prevent education from being reduced to instruction" as Rorty (1980, p. 363) says. In general, hermeneutics as a logic of abnormal discussion (Rorty, 1980, pp. 320–321) needs some other kind of logic than mere interrogative logic. However, even though there may be big differences, the interrogative model can be used in "minor analysis" of the hermeneutical circle (Niiniluoto, 1999).

Closing words

The interrogative model of inquiry allows us to consider the scientific inquiry process as a strategic process. As a strategic process it is a goal-tracking process. However, the goal need not, and usually cannot, be formulated before the process. Science is looking at new knowledge, new truthful and justified beliefs. The search for new truths is not a mechanical process but rather a creative one. There are not, and cannot be, any guarantees that the truths searched for will be discovered. However, the interrogative model allows us to evaluate the processes. The model does not capture the creativity but instead allows us to understand the creativity. The creativity does not presuppose anything mystical or irrational, but rather the usual human intelligent, which does not make itself a prisoner of prejudices. The interrogative model offers a constructive model of reasoning which makes excellence in reasoning more understandable, which in turn allows excellence to be taught and learned; however, human ingenuity and creativity are still needed in scientific inquiry.

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