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Research article

On Scientific Explanation and Understanding – A Hermeneutic Perspective

Arthur Wei-Kang Liu (✉)
Darmstadt Technical University, Residenzschloss 1, Darmstadt, 64289, Germany
a.w.liu@protonmail.com

Abstract

An explanation is a convincing, deductively valid argument that cites at least one law of nature. – This could be a definition of a scientific explanation that takes the notion of understanding seriously because explanation and understanding are intertwined concepts. To arrive at this conclusion, this analysis starts with the question of what makes an explanation an explanation. Philosophers of science have discussed this issue extensively since Carl G. Hempel presented his deductive-nomological model of explanation. It seems that the DN-model offers necessary but not sufficient conditions for explanation. Two prominent problems for sufficient conditions are the problem of irrelevance and the problem of symmetry. For the last seventy years philosophers of science tried to solve those problems, also proposing other possible conceptualizations of explanation, by invoking, for example, causality or contextuality. Those accounts can be brought together in order to solve the problems of the DN-model: By looking at understanding, a new combined account for explanation and understanding could be obtained. After highlighting the advantages and problems of some of the most prominent accounts of explanation, the concept of understanding is analyzed with respect to the notion of hermeneutics. Through Gadamer's discussion of hermeneutics and understanding as well as Kuhn's concept of paradigms, it can be shown that the natural sciences are also deeply rooted in hermeneutics and involve understanding. In the end, it can be demonstrated that understanding and explanation are two interwoven concepts. Understanding is the missing piece of the puzzle to solve the problems of explanation.

Keywords: Hermeneutic Circle; Explanatory Success; Hans-Georg Gadamer; Thomas Kuhn

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Научная статья

О научном объяснении и понимании – герменевтическая перспектива

Артур Вей-Кан Лю (✉)
Дармштадский технический университет, Резиденшлосс 1, Дармштадт, 64283 Германия
a.w.liu@protonmail.com

Аннотация
Объяснение – это убедительный, дедуктивно обоснованный аргумент, ссылающийся на хотя бы один закон природы. – Это могло бы быть определением научного объяснения, которое серьезно относится к понятию понимания, поскольку объяснение и понимание – это взаимосвязанные понятия. Чтобы прийти к такому выводу, данный анализ начинается с вопроса о том, что делает объяснение объяснением. Философы науки интенсивно обсуждали этот вопрос с тех пор, как Карл Гемпель представил свою дедуктивно-номологическую модель объяснения. Кажется, что модель предлагает необходимые, но недостаточные условия для объяснения. Двумя важными проблемами достаточных условий являются проблема нерелевантности и проблема симметрии. В течение последних семидесяти лет философы науки пытались решить эти проблемы, одновременно работая над другими возможными концептуализациями объяснения, ссылаясь, например, на причинность или контекстуальность. Эти соображения можно объединить, чтобы решить проблемы дедуктивно-номологической модели: рассмотрев понимание, можно получить новую комбинированную версию объяснения и понимания. После выделения преимуществ и проблем некоторых наиболее известных подходов к объяснению, концепция понимания анализируется с точки зрения понятия герменевтики. С помощью обсуждения Гадамером герменевтики и понимания, а также концепции парадигм Куна можно показать, что естественные науки также глубоко укоренены в герменевтике и включают понимание. В конце концов, можно продемонстрировать, что понимание и объяснение – это две переплетенные концепции, и что понимание – это недостающая часть головоломки для решения проблем объяснения.

Ключевые слова: Герменевтический круг; Объяснительный успех; Ханс-Георг Гадамер; Томас Кун

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INTRODUCTION

Scientific explanations are important objects of study since Hempel and Oppenheimer's (1948) first influential discussion of it – known as the deductive-nomological (DN) model of explanation. Ever since, philosophers of science have persistently tried to characterize explanations, their goal being to analyze what scientific explanations are, because for many of them, it seems, explanation is one of the primary goals of scientific activity (e.g. Hempel & Oppenheim, 1948; Ladyman, 2002). Explanations seem to be answers to why-question that begin with a 'because.' Yet, by explaining one thing, another follows along: understanding. This is the case because explanations (normally) provide understanding. A number of philosophers of science (e.g. Hempel, 1965a; Kitcher, 1989; Salmon, 1998a) agreed that there is at least some kind of connection between the two concepts. However, scientific understanding was widely neglected in the discussion until very recently (Regt, 2017). This paper shall serve as a contribution to the discussion of scientific explanation and understanding by looking at those concepts from a hermeneutic perspective. The main thesis is that only when the concept of scientific understanding is taken seriously, it is possible to grasp what scientific explanation is, for both concepts are two sides of the same coin.[1] From there, a new account of explanation could be developed.

My analysis starts with a short reconstruction and critique of some of the most influential accounts of explanation: the DN model (Hempel, 1965a), the causal model (Salmon, 1984, 1998b), the pragmatist model (van Fraassen, 1980), and the unificationist model (Kitcher, 1989). Of course, there are other and newer accounts of scientific explanation. Since this paper analyzes explanation and understanding in general terms, it discusses only the 'classics,' which are the departure points also of the newer accounts. In the course of this discussion, I will also identify the two main problems that have to be solved in a theory of explanation: the problems of irrelevance and symmetry. Then, I shall turn to understanding. I start with an evaluation of the influential and systematic conception of understanding which is grounded in a hermeneutic analysis of understanding for the humanities as developed by Hans-Georg Gadamer in 1960. Afterwards I argue that this concept of understanding of cultural artefacts can be transferred into the domain of natural science by an analysis of the term 'paradigm,' popularized by Thomas Kuhn in 1963. From there, I try to outline an account of explanation that is obtained by the preceding analysis of understanding. Finally, I will

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[1] To be sure, explanation is not something that is exclusive to science but is also common in everyday life. Should we, then, just drop the adjective 'scientific' (in the sense of "natural-scientific") (Skow, 2016, p. 524)? I think, at least, for now, it can be said that there is a difference between explaining why the planetary orbits in our solar system are stable or why John did not come to Harry's birthday. In the first case a generalization in the form of a law is usually evoked like Newton's laws of gravity, whereas in the latter case one might say there are some social circumstances like them having had a fight one month prior to the party. *Prima facie* it should be acknowledged that there is a difference between scientific explanations and everyday life explanations. I will restrict myself to scientific explanation because most philosophers of science developed their accounts of explanation under this term, but I hope I will make plausible that the difference between scientific explanations and 'other kinds' of explanations is of degree rather than of kind. The same can be said about scientific understanding.

apply this newly obtained concept of explanation, which is inseparably intertwined with the concept of understanding, by showing that the two major problems I identified before, the problems of symmetry and irrelevance, can be solved by it.

CONCEPTIONS OF SCIENTIFIC EXPLANATION

In order to grasp the concept of scientific explanation, it is necessary to look at the different proposals for a conception of it that have been made so far. Hence, this chapter provides a brief overview of the main models and the criticism that they received. I will start with the modern starting point of a theory of explanation: the DN model by Carl Hempel. One after another I shall present the subsequent models of explanation, beginning with the causal model by Wesley Salmon, going over to Bas van Fraassen’s pragmatic model, and ending with Philip Kitcher’s unificationist model. I will end with Kitcher’s model because all important factors relevant to my goal to set an alternative account of explanation will have been discussed by then.[2] The evaluation of these models will reveal connecting factors for a further discussion with regard to scientific understanding that will in turn illuminate the concept of scientific explanation.

The Deductive-Nomological Model

The deductive-nomological (DN) model has been and still is the most influential conception of scientific explanation of the last century which set the starting point for the contemporary discussion of a theory of explanation. For Hempel (and for many others, as the following sections will show) explanations are answers to why-questions. Hempel divides an explanation into two parts: the thing to be explained (*explanandum*) and the things that explains (*explanans*). His conception is built as follows: The explanans *S* is a combination of laws of nature *L* and sentences about the particular conditions of the situation *C*. Together they form a deductive argument that implies per “logical consequence” (Hempel, 1965a, p. 337) the explanandum *E* as a descriptive sentence of the phenomenon to be explained. Consider the following situation: A gas is sealed in an air-tight container. Now the container is heated strongly, while the volume remains the same. The pressure of the gas is measured before and after the heating and an increase in pressure is detected. This increase can be explained by the ideal gas law. If the volume is fixed and the number of particles kept constant, then the temperature of the gas is proportional to its pressure (*L*). The volume is fixed and the number of particles kept constant (*C*). Therefore, the pressure of the gas rose (*E*) (Ladyman, 2002, p. 204). This conception for singular events can be extended to explanations of uniformities as well, according to Hempel: A law can be explained if it can be shown to be a special case of a more general law.

The DN model faces two major problems, though: irrelevance and symmetry. The first major problem can actually be divided into three sub-problems (Ruben, 1990,

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[2] To be clear, there are newer accounts of scientific explanation (e.g. Strevens, 2008; Woodward, 2004), but I think the best way to get to the fundamental problems of a theory of explanation is to look at the cornerstones of this discussion – especially because newer accounts take the historical discussion and the proposed accounts as a starting point for their own accounts.

pp. 183–188): the ‘original’ problem of irrelevance, the problem of pre-emption, and the problem of overdetermination (Ladyman, 2002, pp. 203-205). For the purpose of this paper, the ‘original’ problem of irrelevance should suffice. The example which is concerned with the ‘original’ problem is borrowed from Ardon Lyon:

(1) All metals conduct electricity

(2) Whatever conducts electricity is subject to gravitational attraction

(3) All metals are subject to gravitational attraction. (Lyon, 1974, p. 247)

Even though (3), the explanandum, is logically deduced from (1) and (2), the explanans, no one would say that (1) and (2) explain (3) because it is obvious that (1) and (2) are irrelevant for the correctness of (3). One would say that all objects with mass are subject to gravitational attraction, so the attribute of electrical conductivity is irrelevant. The DN-model, however, cannot exclude such explanations that cite irrelevant premises.

The problem of symmetry involves biconditionals, which can also take the form of arguments with laws of coexistence such as the coexistence of rise in temperature and rise in pressure. There are two standard examples for the problem of symmetry. The first one is the example just used above to illustrate the DN-model. Because the ideal gas law is a law of coexistence, it is symmetrical, i.e., explanandum and the condition-sentence can be switched. This explanation also satisfies the conditions of the DN-model, while explaining the rise in temperature by the rise in pressure, but we would not normally say that the latter is the actual explanation. The other standard example is that of the flagpole: Why is the shadow of the flagpole X meters long? Knowing the height of the flagpole and the angle between the ground and the sun (assuming that light rays are linear), the length of the shadow can be derived in order to explain it. But this is the problem: In the same manner the length of the shadow and the incident angle can also be used to derive the height of the flagpole, and thus to explain it. Surely, many, if not all, would say that only the first derivation would count as an explanation.[3] The DN-model, thus, fails to determine the right direction of explanations (Bird, 1998, p. 74).

Though it evidently cannot provide sufficient conditions for explanation, Hempel’s account still seems very convincing. Some philosophers of science therefore think that the DN model provides the necessary conditions for explanation (e.g. Friedman, 1974; Woodward & Ross, 2021). In that case, the remaining task is to eliminate the problems of irrelevance and of symmetry. The solution that suggests itself is the notion of causation. In my outline above I avoided the notion of causation because Hempel himself thinks that it is not necessary for the conception of explanation (Hempel, 1965a, pp. 353–354), but if one recalls the counterexamples above, some of the problems can be solved by including causation: It is the mass and not electrical conductivity that causes gravitational attraction. The increase in temperature causes the rise in pressure. The light and the flagpole cause the length of shadow but light and shadow do not cause the length of the flagpole.

[3] In this case, it seems that the second “explanation” is either aimed at a why-question that requires a very different answer (Why does the flagpoles have height X?), or it is not aimed at an explanation-seeking why-question at all: How tall is this pole?

The Causal-Mechanistic Model

One of the most prominent advocates for a causal conception of explanation is Wesley Salmon (1984, 1990). According to Salmon, a phenomenon can be explained by showing the causal history or mechanisms that led to the phenomenon. To understand this correctly, some terminology has to be introduced.

For Salmon a causal interaction is “an intersection of two processes […] if both processes are modified in the intersection in ways that persist beyond the point of intersection, even in the absence of further intersections” (Salmon, 1990, p. 7). For example, if two cars collide, both are modified by getting dents, and those modifications persist beyond the point of collision (Woodward & Ross, 2021). The basic criterion for distinguishing a causal process from a pseudo-process is the causal process’s ability to transfer a mark. In the example given above, the two cars did not have any dents until collision, and those dents were then the marks that were transferred. Therefore, a process is causal if it could be permanently altered through an intervening causal interaction (Salmon, 1984, p. 142). Furthermore, it should be added that the transfer of those marks is spatiotemporally continuous, that is, there is a continuous connection between the causal process and the causal interaction which transfers a mark. In other words, the mark can be traced back to the process via a spatiotemporally continuous connection (Salmon, 1998a, p. 116).

Salmon’s account needs laws of succession that state the temporal development of a process or interaction, but there are also laws of coexistence that only limit the space of possible configurations of a system (van Fraassen, 1980, pp. 122–123). The ideal gas law is one of them. An explanation of a state of a system would then be non-causal for there is not any action involved, and thus the explanation would be non-explanatory on Salmon‘s account. Another problem is connected with quantum mechanics. As the EPR-Paradox shows that locality is violated in quantum mechanics. Therefore, since the process is not spatiotemporally continuous, there would appear to be non-causal processes in quantum mechanics. In these cases, there cannot be a causal explanation, according to Salmon’s account.[4]

The Pragmatic Model

Because of the problems of Salmon’s account of causal explanation, van Fraassen (1977, 1980) takes another approach to explanation. By analyzing the role of causality in explanation from another perspective, he arrives at what he calls the pragmatist account of explanation. The basic idea is that explanation is highly context-sensitive, that is, the circumstances and the people involved in an act of explanation are essential if one wants to understand causality.

He begins with an analysis of the principal idea of causal explanation. As presented by Salmon, by exhibiting the causal forks explanation shows how “[e]vents are enmeshed

[4] Salmon is aware of this problem, he even describes it as „a source of great distress“ (Salmon, 1998a, p. 115) but does not seem to have an answer for it in his framework of causal explanation. He actually refers to the unificationist model of explanation, for example, as a possible solution to the explanatory difficulties of quantum mechanics.

in a net of causal relations" (van Fraassen, 1980, p. 123). He argues that explanation thereby highlights the salient factors in that part of the causal net which leads up to the event to be explained. Accordingly, events do not normally only have one explanation but more: there are as many causes for an event X as there are explanations of X. The salient factors are themselves determined by the contextual factors, namely the interests and orientations of the questioner along with the phrasing of the problem.

The pragmatic model also takes explanations as answers to why-questions, so it starts with an analysis of why-questions and concludes that adequate answers to a why-question are context-sensitive. That means that the adequate explanation varies from context to context and on what is actually asked. Consider the question 'Why is this conductor warped?'. The proposition, this conductor is warped, is the topic of the question. The contrast-class is the set of alternative interpretations of a particular question, constituting a set of propositions including the topic. This can be highlighted by putting emphasis on a single expression: Why is *this* (rather than another) conductor warped? Why is this conductor *warped* (rather than not)? Here the explanatory relevance has to be introduced in order to grasp the context-sensitivity of the topic and its relation to its contrast-class. An explanation would then show that the topic is true, that only the topic is true in its contrast-class, and that minimally one proposition bears the relevance relation to topic and contrast-class (van Fraassen, 1980, pp. 141–144).

Van Fraassen seems to believe that "[f]or any two propositions there is a candidate relevance relation that the first bears to the second" (as cited in Skow, 2016, p. 540). This means that for any pair of two propositions exists a context in which the first proposition is relevant for the second one. Salmon and Kitcher showed that van Fraassen's model cannot discriminate between good and bad explanations, for there is not any constraint on the relevance relation. Consequently, as long as van Fraassen does not propose criteria for genuine relevance relations "almost anything can explain almost anything" (Salmon, 1998, p. 183). Nonetheless, van Fraassen's account provides an important insight into the relation between idealized (scientific) explanations to the practice of explaining in everyday life, as well as the reconstruction of explanations as answers to contrastive why-question.

The Unificationist Model

Michael Friedman (1974) and Philip Kitcher (1989) introduced the unficationist model of explanation. They take scientific understanding as the goal of explanation by unifying scientific theories, thereby bringing explanation and understanding explicitly together. Due to the problems of Friedman's version (see e.g. Salmon, 1998c, p. 70), Kitcher's version will be discussed here.

The idea of the unificationist model is quite simple: An acceptable ideal explanation is part of the explanatory store *E(K)*, where *K* are all statements that are accepted by the scientific community. The explanatory store *E(K)* is the set of derivations with the maximum systemization of *K*, while having fewer argument patterns than other systemizations of *K*. To understand Kitcher's model, one needs to introduce some technical terms: A schematic sentence is a sentence in which some of the non-logical words have been replaced with dummy letters. A set of filling instructions for a schematic sentence gives the information on how to fill in the dummy letters; for each term one filling instruction is needed. A sequence of schematic sentences is called a schematic argument. Furthermore, a set of sentences that describes the connections between the schematic sentences of the schematic argument is called classification for a schematic argument — it states which sentences are the premises, which are inferred from which, and which rules are used. Lastly, a general argument pattern consists of a schematic argument, a set of filling instruction and the classification for the schematic argument. In order to compare different argument patterns, Kitcher introduces the criterion of stringency (Kitcher, 1989, pp. 432–433).

He agrees with Hempel that ideal explanations are derivations, in fact, he thinks that "[*i*]*n a certain sense*, all explanation is deductive" (Kitcher, 1989, p. 448), but, contrary to Hempel, derivations are sequences of statements whose status is clearly specified, therefore showing how exactly to deduce the conclusion from the premises. In general, it can be seen as a "sophisticated version of Hempel's deductive-nomological model" (Regt, 2017, p. 53).[5]

Kitcher's account also solves the problems of irrelevance and symmetry. Let me shortly discuss them. Consider Lyon's example again. It stated that all things that conduct electricity, including all metals, are subject to gravitation. However, by referring to the fact that all masses are subject to gravitational attractions, one cannot only deduce that all metals are subject to gravitational attraction but any object with a mass, so this pattern can derive the conclusion for metals and any other material, while in Lyon's example it can only explain it for electrical conductors, requiring analogous explanations for non-conducting masses. Therefore, to explain gravitation as a feature of all masses provides a more unified account and an actual explanation.

The second problem concerns the flagpole. In principle, the height of the flagpole can be deduced from the length of the shadow and the position of the sun. Call the standard systemization which has the length of the shadow as its conclusion *E(K)* and the one which has the height of the flagpole as its conclusion *S*. Kitcher states that *E(K)* contains the "*origin-and-development*" pattern (Kitcher, 1989, p. 485). He goes on to note that the dimension of an object can be traced to the condition of its origination and the undergone modifications, so this pattern provides an explanation of the current size of an object such as the shadow by giving its history. If the pattern for deriving the size of an object by the length of its shadow is added to *E(K)*, an unnecessary pattern would be added because it does not provide any new conclusions, only serves to increase the number of patterns. This means that *E(K)* is indeed the more unified generating set, so *S* is not explanatory (pp. 485–487).

Even though Kitcher's account seems quite convincing, it is confronted with at least the following two problems. The first problem concerns the problem of symmetry involving laws of coexistence. It seems to me that Kitcher's account also fails to

[5] Due to the focus of this paper, I have not discussed a more technical problems of the DN model. It concerns the characterizations of laws of nature. The derivation of a law from a more general law can always be done by the conjunction of the law to be deduced and another law, which would then be a more general law, but this derivation would surely not count as an explanation (Hempel, 1965b, p. 273). Kitcher can handle this problem (see Regt, 2017, p. 53).

distinguish the right from the wrong direction of explanation. Because both directions are in principle explanatory, without one entailing the other like in the flagpole example, it is not possible to exclude one of them from *E(K)*.

Moreover, there seems to be serious problem with what Woodward (2004) calls the "'winner-take-all' conception of explanatory unification" (p. 367). Since Kitcher considers only the unifying explanation as a proper explanation, every other explanation not part of *E(K)* is not explanatory. There is no degree of explanatoriness. For example, the theory of relativity is more unified than classical mechanics, so explanations that use classical mechanics are not explanatory according to Kitcher's account, though no one would deny their explanatory value.

Despite all the objections, Kitcher's approach lays bare a possible way of systemizing theoretical thoughts. Even if the greatest possible unification is not a necessary condition for successful explanation, it can be said that unification is at least a virtue of explanation.

Interim Result

The historical development of the discussion shows some general motives and problems that seem to be central to the conception of explanation. Firstly, every model of explanation tries to solve the two problems regarding the sufficiency of Hempel's DN model: irrelevance and symmetry. All models try to state criteria to eliminate irrelevant factors from explanations and to account for the asymmetry of explanation. Furthermore, some concepts seem to be central to the ongoing discussion of the two problems: causality, and thus temporality, and explanation as a concept with theoretical and pragmatic components. All those concepts can be brought together, and so the two problems can be solved, by turning to the notion of understanding.

SCIENTIFIC EXPLANATION AND UNDERSTANDING

The following section is dedicated to the notion of understanding, for which I will analyze its relation to explanation. This undertaking might seem a bit questionable, at least from the perspective of German philosophy. It was Wilhelm Dilthey (1883/2017) who made a distinction between two different ways of acquiring knowledge, namely explanation and understanding. He did so in order to legitimize the status of the humanities [*Geisteswissenschaften*] as epistemically valuable (Grondin, 2012, p. 123). Roughly said, understanding is the domain of the humanities because the objects of understanding are the products of the human mind that one has to 'relive' in order to understand what their author meant. Hermeneutics was the method of the humanities, as the correct way of interpreting a text in order to get to the intended meaning and thus an understanding of its author (Grondin, 2012, pp. 128–129). The processes of nature, on the other hand, cannot be 'relived' because there is no inner, perhaps psychological, character to follow and grasp, so the task then is to explain them. The phenomenological turn initiated a new perspective on hermeneutics and understanding, first picked up by Martin Heidegger (1926/1967) and then criticized and further elaborated by Hans-Georg Gadamer (1960/2010) in his work *Wahrheit und Methode* [*Truth and Method*].

Gadamer‘s universal hermeneutics [*Universalhermeneutik*][6] provides a conception of understanding which want to discuss here since it was widely received and also discussed in the context of a hermeneutics of natural sciences (see e.g. Bernstein, 1983; Heelan, 1977).

Understanding of Cultural Artefacts

I will discuss here the paradigmatic example of cultural artefacts that are in need of an interpretation: texts. The old problem of the hermeneutic circle arises here directly. A text can only be understood by its parts, but an understanding of the parts can only be available if the text is already understood, but it is then questionable how one should even, in principle, be able to understand a text. The answer is preconceptions [*Vorurteile*], conveyed by, for example, tradition and authorities like parents or teachers. If one reads a text, one either already has an idea of what the text might be about or begins to read it without prior knowledge of the text and draft a possible interpretation while reading it, but either way it seems that the reader is trapped in his or her preconceptions about the text. However, Gadamer emphasizes the positive aspect of preconceptions that especially come to the fore when discussing hermeneutic circle. Only because one has such preconceptions it is possible to even try to understand a text. Preconceptions are fundamental for our ability to understand, but that does not mean that the preconceptions are always right. Every text can be understood in at least one correct way and many incorrect ways. The task is to work out an interpretation of the text that is in itself acceptable, that is constructed in a manner that displays the content so that it is coherent, because the only things that can be understood are things that have united meaning. In the process of continuously drafting and redrafting interpretations of a text while reading it, one comes to an understanding of the words by seeing that maybe some of them have other meanings than presupposed. In turn this is only possible if one recognizes and acknowledges that the text could have a different view on the same matter. For real understanding of someone else’s view, as expressed in a text, one needs to be open to the possibility that the expressed opinion is true, thus risking also the need to acknowledge that one was wrong. Understanding always requires checking if one’s own preconceptions are true, to be adjusted or completely rejected, by valuing and weighing them against each other, all the while connecting them to old and new ideas. Thus, it is exposing them to further scrutiny (Gadamer, 2010, pp. 270–275). For Gadamer, the hermeneutic circle is, therefore, a productive circle.[7]

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[6] To be sure, when Gadamer discusses and elaborates the conception of understanding as an alternative to (natural-scientific) methods in order to obtain truths, he is occupied with the legitimation of the humanities as proper sciences as distinct from the natural sciences. He was convinced that there is no hermeneutics of natural sciences (Kisiel, 1997, p. 331). This paper is also an implicit critique of Gadamer insofar as he was too hesitant with his claim of a universal hermeneutics.

[7] It is important to note that hermeneutics and the hermeneutic circle is not referring to a method or so as did Schleiermacher. Rather, hermeneutics comes into play as soon as we seek to understand anything in the world. Here, Gadamer is following Heidegger’s ideas. For him, the hermeneutic problem concerns the phenomenon of understanding and adequate interpretation [*Auslegung*]. The task of hermeneutics is to explore and reveal the requirements of understanding (Gadamer, 2010, p. 300).

An important concept in Gadamer's analysis is the horizon. A horizon is defined as a "ken that encompasses and encloses everything that can be seen from one point of view" (Gadamer, 2010, p. 207, my translation). It contains everything a person already knows and understands. When one tries to understand a text which has, so to speak, its own horizon, the unfamiliar is made familiar. That means one can judge the claims and accept, adjust or reject them by giving reasons. One can, so to speak, work with them. Thus, Gadamer is speaking of the merging of horizons because the ideas of the text become part of the reader's horizon. The ideas of the text can be related to all other ideas already understood.[8]

In this sense understanding can be characterized as an ability and skill which entails interpretation, justification and application. When one tries to understand a text, it means already interpreting, but by interpreting it, one has to think about the justification of the interpretation because others could always ask for one. Finally, a text as conveyer of truth claims challenges the reader's judgement of the things it claims to have knowledge about. So when a reader really wants to understand something, he or she already needs to know whether and why the claims are justified or not. But this application of ideas is only possible because of prior interpretation. Moreover, by applying, that is discussing and judging ideas, an interpretation might change as well. So understanding always imply all these dimensions at the same time.

In conclusion, understanding is knowing how the different concepts in a text are related to each other and how those are related to the situation of the reader. All preconceptions and prior knowledge are ordered and related, and if one reads a text that makes truth claims, one is challenged to take a stand. Either way it demands one to question one's own understanding of the matter in question by showing that there were unknown or only seemingly existent connections, thereby 'forcing' an adjustment of the understanding.

Scientific Understanding

After talking about the understanding of texts, what could scientific understanding mean? A rather striking analogy appears when looking at Kuhn's discussion of paradigms. Kuhn describes paradigms as having laws, theory, application, and instrumentation. A paradigm tells the scientist what they have to look out for, what exists, how they can access things and measure them, what concepts mean and how they are related to the world and so on. It contains the things a student has to learn to be part of a scientific community. This learning process is guided by the application of concepts, laws, and theories. In order to be able to operate in a given paradigm, one has to know

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[8] The distinction of two separate horizons only arises as one becomes aware that there are two different horizons involved: mine and the other's (Gadamer, 2010, pp. 307–312). Subsequently, one needs to translate the language of the other horizon into one's own which is already part of the process of understanding because translating presupposes the understanding of the thing that is expressed. This process of translation can be thought of as looking for a common language in which one's own horizon and the other's can be understood simultaneously, implying that the view of a text on a specific matter is put into relation to other possible views that are familiar to oneself, thereby coming back to the merging of horizons (Gadamer, 2010, p. 399). Translation implies that the unfamiliar view is applied to the reader's situation. It thus does not leave the reader unaffected, since one acquires new perspectives on the matter in question.

how to apply specific concepts, laws or theories to a specific problem or situation (Kuhn, 2012, p. 47). He or she learns to see the world through the lens of the paradigm. In this way, paradigms become self-contained, incommensurable world views that span a net of concepts, which I call the conceptual net of the paradigm.

A paradigm conveys specific preconditions for it states what entities in the world exist and how they are related to each other. So, different paradigms convey different world views as the same things are seen differently (Crease, 2002, p. 37). Each encompasses everything that is familiar and understood, it also encloses it unambiguously because the problems, the things not yet understood, are clearly defined (Kisiel, 1971, p. 198). The problem of the hermeneutic circle arises here again (Kisiel, 1976, p. 181). In order to identify a phenomenon as a phenomenon one needs to already know what the thing is. Categories and relations are needed in which this phenomenon can be embedded. Instead of the text that tries to express the matter, it is now the phenomenon that is brought to expression by measurement (see also Wu & Hu, 2023). The little difference here is that during a stable period of a paradigm the data is already put into established categories, but even here some mapping of theory onto praxis must be done. The experimenter has to know how to prepare the experiment so that the things the theory talks about will be reflected in the experiment (Crease, 1995, p. 112). Afterwards the experimenter has to interpret the results: Are the results as expected? If not, why? Here, too, a merging of horizon can be seen: the horizon of the scientist within the paradigm and the horizon of the phenomenon manifested through measurement. While scientists interpret the data, they try to find a common language for both horizons and thus integrate the data into the net of concepts already known, as the gathered data is necessarily new, that is, unfamiliar. If that is not possible, then the paradigm has to be adjusted or replaced by another.

This aspect becomes even more apparent if the time of change of paradigms is analyzed. The case of classical and relativistic physics is a good example. Kuhn demonstrated that in order to understand Newton as a special case of Einstein one has to reinterpret basic concepts of Newton such as time and space. This kind of merging of horizons corresponds to Gadamer’s idea of understanding because Newton and Einstein make truth claims about things in the world. As a supporter of Einstein, one has to take the claims of Newtonian mechanics seriously and thus try to find a common language where both horizons could be understood simultaneously. This does not mean that one has to agree with the other position, rather it enables one to judge it (Kisiel, 1971, p. 207). As the theories are incompatible, one has to reject basic assumptions, but cannot therefore reject the laws of Newton, since these are empirically adequate. From the point of view of an Einsteinian, one has then incorporated und thus understood Newtonian mechanics as a part of Einsteinian mechanics. And again, the thing that is the gauge for judging this, is the phenomenon in question.

To conclude, paradigms are like horizons because they convey preconceptions about the world, everything that is already familiar. Another possible paradigm always challenges the ruling paradigm in its truth claims. If there is a change of paradigms the ideas and claims of the old one are understood in the new one either as in some way incorporated or as refuted. Either way propositions about the world are being set into relation to other propositions. The gauge here is the phenomenon to be understood. By looking for a common language of both horizons, one comes into the process of understanding which leads to a fusion of horizons where the claims of the unfamiliar horizon to one's own preconceptions and understanding of things can be judged. Even without the direct challenge of another possible paradigm understanding is always involved in science. For the experimenter it is the mapping of the theory onto the experiment. It is not the measurement itself but also the analysis of the gathered data afterwards. The still unfamiliar data have to be put into relation to the experimenter's horizon. Here, too, fusion of horizons can be observed because the 'language' of the experiment must be translated into the language of the experimenter's own horizon. In the end, scientific understanding of phenomenon or experiment therefore involves the transformation of the unfamiliar to the familiar, and by doing this, either adjusting or affirming one's own knowledge about the world, that is, what exists, how things are related, and in which way they are accessible through experimentation.

The Connection Between Understanding and Explanation

After specifying what (scientific) understanding is, I can turn to the connection between understanding and explanation and show that the connection is an essentially close one. I will also analyze the difference between giving and receiving an explanation for something. This difference is significant in that it will highlight some nuances of explanation that are foreshadowed in van Fraassen's discussion of the importance of context.

First of all, it has to be acknowledged that mere statements in and of themselves do not explain anything, even though everyday language suggests this when one says that Newton's law of gravitation explains the tides. Rather, explaining takes place only when someone is using Newton's law to explain the tides. This is because the theory and its categories have to be applied to a specific case, and that means that the person explaining already understands Newton's theory and knows which concepts are involved and how they are related. As shown above, application is always already understanding. Therefore, the person explaining must already have understood the phenomenon of the tides as well, that is, knowing how it fits into the conceptual net of the paradigm, in order to explain it. Explanation in this sense is just to exhibit the place of the phenomenon in the conceptual net of the paradigm. For example, it is one important aspect of classical mechanics that it works fine on earth and that it is empirically adequate, even though inferior to relativistic mechanics. The explaining person understands the paradigm of relativistic mechanics in a way that allows for the judgment that classical mechanics is still *good enough* as an explanation.

This view changes as soon as the roles of the explainer and the questioner are reversed. As the questioner one normally genuinely does not understand the phenomenon because one does not know how to fit the phenomenon into the conceptual net of the paradigm. This is, contrary to the case above, the normal situation in scientific research. Two different situations have to be distinguished here. In the first case the questioner is also the explainer like a scientist who tries to understand a new phenomenon or collected data, and in the second case the questioner asks someone else who already understood the thing in question. Let me first discuss the former case. There are many phenomena that are not explainable within the ruling paradigm, which means only that they are not (yet) understood. Here, the boundaries between explainer and questioner become blurry. As one poses the question, one also tries to come up with an explanation. In the process of explanation-seeking the scientist comes up with different candidates for an explanation but judges them by their fit with regard to the paradigm. If and only if an explanation can be found, the phenomenon is understood. There is obviously a difference to the other situation where the unknowing questioner meets a scientist who has the answer. This difference is not, however, whether understanding comes before explanation since one can only explain if and only if one already understands. The difference is instead one of the kinds of activity connected to each situation. In one case the phenomenon is already understood and the explanation is just asked for afterwards, whereas in the other case the process of coming up with an explanation is part of the process of gaining understanding.

In the former case the questioner looks for an explanation of a phenomenon from a person that already understood it. In this situation, explanation should provide understanding. The explainer exhibits how the phenomenon fits into the conceptual net of a paradigm. The thing here is also that the explanation is only explanatory if it can be understood from the point of view of the questioner. Here, again, a merging of horizons occurs: an explanation is explanatory for a questioner only if the questioner is introduced into the horizon of the paradigm. That also implies that a questioner who adheres to one paradigm does not initially judge as explanatory an explanation phrased in terms of another paradigm. The questioner has to go through a process of understanding in order to be able to even grant the explanation any degree of explanatory power.

Therefore, it can be said that understanding is an ability to potentially provide explanation and explanation is a social act that is set in a context, while an explanation is only explanatory when it provides understanding, that is, can be fitted into the horizon of the listener. Explanation is, thus, showing the place of the phenomenon in the conceptual net of the paradigm. Here one can see how deeply and inseparably connected both concepts are. Understanding only makes sense by being theoretically able to provide explanations for a phenomenon and explanation only makes sense when it relates to the realm of understanding. Coming back to a conception of explanation, the definition could be rephrased as follows: An explanation is a convincing, deductively valid argument that cites at least one law of nature.[9] By adding "convincing" to the definition, the dimension of understanding is added to it because convincing means that it must fit the context and there must be good arguments for the explanation to be the right explanation for a phenomenon. In this sense, the quite technical criteria of logical derivability – also

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[9] I am here mostly concerned with the natural sciences, but this definition can be easily modified for the humanities, social sciences and everyday explanations. Instead of 'law of nature' it might be enough to say 'common pattern' or 'general rule.' Let me just make some plausibility arguments. Take the question "Why did John not attend Harry's birthday party, despite being close friends?" Two possible explanations could be "Because they had a huge fight the week before" or "Because John is in hospital due to an accident." Both explanations cite a common reason why someone is not attending a social event, and these reasons can be rephrased as common patterns: Whenever two people have a huge fight, they will normally need time apart, or whenever someone is seriously injured, he or she will not attend social events shortly afterwards. To be sure, whether the explanation is explanatory is still context-sensitive and it is only explanatory if it is convincing.

involving, as shown above, instrumentation, experimental preparation and theory (application) – are supplemented or rather complemented by communicative practices working with reasons within the sphere of understanding.

Three Possible Objections

There could be three objections I want to discuss shortly. The first one is directed at my conception of (scientific) understanding: relating the unfamiliar to the familiar, therefore making the unfamiliar familiar. It could be argued that science also uses unfamiliar concepts to explain phenomena. An example is the use of microphysical entities in quantum mechanics. This observation is important, and I think it actually supports my conception of understanding. Consider, again, my initial question: When is an explanation explanatory? In order for a newly introduced concept to be explanatory with regard to a phenomenon, it has to be already related in the conceptual net of the paradigm, that is, how it is related to all other concepts. Only when such a place can be found, an (unfamiliar) concept can be used in an explanation, otherwise it would be questionable what this concept might even mean. But since the concept is put into relation, it is already understood and not unfamiliar anymore. In other words, the scientists operating with a new concept must make themselves familiar with it. It is like the situation I discussed above: coming up with a new explanation for a not yet explained phenomenon. After publishing their idea, other scientists need to understand the new concept, too, and consequently judge if it makes sense to introduce such a new concept. This situation can be compared to that of first-year bachelor's students. They learn many concepts that are unfamiliar to them but that are used to explain things. However, by studying, using, and discussing them, they make themselves familiar with them. One has always to keep the perspective in mind: For whom is a concept unfamiliar?

The second objection is that not every explanation seems to cite laws and is aimed at the idea of the DN model. Consider the question "Why did the chair fall over?" An acceptable explanation could be that it fell over because John kicked it. This explanation works in everyday life because it fits into possible experiences of everyday life, but for a trained physicist, this explanation would not be the whole story, at least not in physics because this explanation is compatible also with the chair not falling over (even though John kicked it). If the chair fell over because John kicked it, other conditions come into play which physicists know as tilting moments and forces acting upon them. Physicists will thus invoke laws to explain the tilting over of the chair.

The other objection is more fundamental. One can always ask "why?" again after listening to an answer to a why-question. At some point no adequate answer can be given anymore, but if explanation and understanding are inseparably connected, do we then really understand anything? This argument overlooks something because it is normal that the why-chain comes to an end. For example, if someone asks me why there was a poor harvest this year, I could say that it was because of the severe drought. Even if I cannot say why this drought occurred in the first place, this answer is still explanatory because the concept of drought and its effects are known and can explain the poor harvest.[10] The

[10] Neil Cooper (1994) categorized understanding in more detail. He distinguished, first, between semantic and cognitive understanding. Semantic understanding is just the understanding of words. I know what the

following why-question of why the drought occurred could be an unknown connection in respect to understanding that is yet still to be found or rather made.

THE PROBLEMS REVISITED

Let me come back to the problems of irrelevance and of symmetry and show how this enriched concept of explanation can solve the aforementioned problems. The problem of irrelevance was illustrated by the example of the conductivity of metals. One can see that the fact that something is an electrical conductor is irrelevant for its being subject to gravitation. But why is it irrelevant? This is because in the conceptual net or paradigm of relativistic and classical mechanics there is no connection between gravitation and electric conductivity. The one and only concept that is connected to gravity is mass, so we cannot think of this explanation as explanatory because we already understand that only mass and gravity are directly linked together. Furthermore, we know that all conductors as objects have a mass, so we already know how to fit into our paradigm the phenomenon that conductors are subject to gravitational force. The information about its ability to conduct electricity, thus, can only be seen as completely irrelevant.

I introduced two examples for the problem of symmetry. The first problem concerned the explanation of the rise in pressure by the rise in temperature, connected to the ideal gas law. It is now clear that only one direction is explanatory, at least in this case. The scientist conducting the experiment will prepare an experimental setup such that the pressure of the gas is measured depending on its temperature which can be controlled through a heater, for instance. This experimental setup only allows one direction of explanation; the other seems abstruse in light of the experimental context and the implied causal chains, In fact, the other direction will not even come to the scientist's mind because it is quite trivial in this case.

The other problem was about the height of a flagpole and the length of its shadow. From the angle under which the supposed linear light rays hit the flagpole and the height of the flagpole, the length of the shadow is derivable. Due to the symmetry of the geometrical equations used, one can also deduce the height of the flagpole from the position of the sun and the length of the shadow. However, through personal experience and the physical paradigm involved, one can only say of the first deduction that it is explanatory. There are two possible reasons for this. First, one learned through interaction with the world that the darkness of a shadow is equal to the absence of light, so light is something in the world and darkness is only defined as the absence of light. Therefore, a shadow means that some of the light is blocked by an object, for the shadow is visible as an enclosed form within a surface that is lightened. This belief within the paradigm is also supported or influenced by our experimental practice. We can change the length of the

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words in a description of a volcano mean. Cognitive understanding, on the other hand, can be described as finding one's way and seeing connections between things, like knowing the possible effects of a volcano and its connection to other phenomena. This metaphor aligns well with the one of the conceptual net provided by a paradigm. His analysis is more thorough and could be a starting point to characterize understanding in more detail.

shadow by changing the height of the flagpole, but the opposite does not hold true.[11] I think this becomes also apparent by thinking about the implied why-questions: Why does the shadow have length X? Why does the flagpole have height X? In the former case, one directly thinks about the incident angle of the light and the flagpole as explanatory necessary and relevant factors, but in the latter case, one thinks instead of social, functional, or material factors that influenced the manufacture of the flagpole. In fact, physically speaking, it seems quite absurd to think that the height of the flagpole is determined by the length of the shadow. Again, our understanding of the construction of flagpoles predetermines the space of possible answers, rendering some unthinkable. The problem of symmetry can, therefore, be solved by invoking causality, and the problems of causality itself are solved by including the dimension of understanding. The paradigm entailing laws, theory, application, and instrumentation manifests the causal relations in accordance with the theoretical and the practical dimensions of science.

CONCLUSION AND OUTLOOK

What I have shown is that the concept of understanding joins the different accounts of explanation and solves the two major problems of the DN-model. An explanation can be defined as the active exhibition of the location of the phenomenon in the conceptual net of a paradigm. The goal of an explanation is always to provide understanding for the person that asks for one. This becomes particularly clear when one recalls that understanding is the knowledge of the relations of entities in the world, so explanation must indicate the right way of understanding a phenomenon. Once more, this demonstrates how the two ideas are inseparably linked because in order to invoke one, the other must also be invoked. Together with the characteristics of explanation stated above, an outline of a possible account of explanation can be obtained that is developed from the notion of understanding.

I think this discussion of (natural) scientific explanations can be extended to explanations in the humanities, social sciences, and everyday situations because of the interwovenness of theoretical and pragmatic considerations. A purely empiristic view of explanation is consequently not tenable. In the end, a universal theory of explanation could be obtained. This, in turn, questions the categorical divide between natural sciences and humanities, thereby bringing them closer together.

As a contribution to a hermeneutics of natural science this approach showed that explanation and understanding are two sides of one coin. Therefore, this approach can help us get a better understanding of situations where explanations fail to provide understanding. In fact, it gives us criteria for successful scientific communication, as explanations are means to provide understanding for a questioner. Importantly, however, one of these criteria is not a criterion, technically speaking. Only time will tell whether an explanation meets the „criterion“ of being convincing – but from a hermeneutic perspective one can spell out what is entailed, culturally and linguistically, in the kind of understanding that renders explanations convincing.

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[11] This argumentation is similar to the manipulist account of explanation (Woodward, 2004). This supports my initial claim that understanding binds the different conceptions of explanations together.

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СВЕДЕНИЯ ОБ АВТОРЕ / THE AUTHOR

Артур Вей-Кан Лю, a.w.liu@protonmail.com
ORCID 0000-0001-7564-110X

Arthur Wei-Kang Liu, a.w.liu@protonmail.com
ORCID 0000-0001-7564-110X

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