

What Is Scientific Misunderstanding?

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ABSTRACT

We present the negative phenomena of understanding in relation to scientific explanations. We begin by formulating the distinction between genuine understanding and lack of understanding, to define the epistemic category of misunderstanding. We illustrate misunderstanding with a short meta-philosophical study on the current debates about distinctively mathematical explanations.

KEYWORDS

Explanatory Understanding; Epistemic Inclination; Misunderstanding; Phenomenology; Distinctively Mathematical Explanations

Human beings understand nature in many ways, through mythology, science, or religion. Sometimes the ways we understand a certain phenomenon are in conflict. In these situations, we often misunderstand each other.

Today we shall focus on defining misunderstanding in scientific knowledge. We are going to restrict our discussion to understanding based on scientific explanations, or the so-called explanatory understanding. We are going to investigate two central, inter-related questions – “When do scientific explanations fail to generate understanding?” and “When does explanatory misunderstanding occur?”

To begin with a bit of background, the classical literature of the logical positivists discusses understanding within theories of explanation. For instance, Hempel and Oppenheim (in Hempel, 1965) analyse understanding as a psychological by-product that arises from sound deductive arguments. For explanatory unification, understanding is a by-product of explanatory conceptual frameworks that are repeated serially to cover as large as possible factual domains. For causal theories, understanding can be seen as a pragmatic matter of being able to potentially influence the explanandum through its causes.

Only recently have epistemologists and philosophers of science begun to view understanding in its own right, such as Kvanvig (2003) in epistemology, and Kitcher (1989), de Regt (2017), and Khalifa (2017) in philosophy of science. These recent theories of scientific understanding have, to a degree, decoupled understanding from explanations. We see this as a double-edged sword. This separation has brought interesting analyses of potential vehicles of understanding other than explanations, such as graphics (de Regt, 2017), exemplars (Elgin, 2017), or scientific models broadly considered (Dellsén 2020). On the other hand, some have seen this separation as a misstep and have tried to

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reduce other forms of understanding to explanatory understanding (Khalifa 2017).

The proliferation of theories of understanding and the debate about the reducibility of other vehicles of understanding to explanations have made it significantly difficult to provide a unified account of scientific understanding and its norms. This is concerning, since the lack of a somewhat unified standard of understanding threatens us with introducing numerous *ad hoc* theories of understanding. This can lead us to an “anything goes” approach, a sort of dogmatic position that “whatever scientists do they always reach some understanding”. As such, it has become difficult to analyse the common pitfalls that epistemic subjects might face in their attempts to reach understanding.

In this talk, we are going to “return to the roots” (so to speak) by making a step in the direction of providing a unified account of understanding, with a focus on explanatory understanding. That is, we are going to focus on the conditions and failures of reaching understanding, when explanations are the exclusive vehicles of information.¹

To pick up the threads, we begin with a sketch of a definition of *explanatory understanding*, based on both theories of explanation and of understanding. From there, we are also going to bring to light what we see as a previously unmarked phenomenal and cognitive feature of understanding – that the epistemic success of understanding reinforces epistemic inclinations. Turning our attention to the negative spectrum of understanding, we analyse the situations when understanding does not arise, as *lack of understanding*. We define it as resulting from a lack of epistemic skills and abilities or a lack of correct explanations.

With these two end points of the epistemic spectrum of understanding, we introduce the situation of *misunderstanding*. As we define it, misunderstanding occurs when one’s epistemic inclinations do not align with an otherwise correct explanation. Therefore, misunderstanding is distinguished from a lack of understanding, by the rejection of a correct explanation in the presence of necessary cognitive abilities and skills for its grasping.

To make a comparison to Hempel, he sees understanding as a psychological by-product of cognitive agents capable of grasping a correct scientific explanation. Here, instead, we shall show that epistemic agents, even when capable of grasping a correct explanation, sometimes fail to do so, and thus fail to achieve understanding. This is because, while an explanation is correct, it can fail to satisfy one’s subjective *epistemic inclinations*.

We begin with a simple definition of explanatory understanding:

Understanding is an epistemic achievement that results from (*subjectively*) grasping or constructing the (*objectively*) correct explanation for a given fact.

Let’s try to unpack this. Starting with the objective component in our definition, the natural

¹ Here we are to argue for explanatory chauvinism. We believe (similar to the early claims of Khalifa) that the logical positivists are on the right track and that scientific understanding in particular requires the implicit or explicit presence of explanations. The only argumentative sketch for explanatory chauvinism that our talk might involve is that explanations are conceptual linguistic artifacts and scientific understanding requires an explicit conceptualization of the problem that scientists aim to solve. Since scientific progress is carried mainly by publishing papers and communicating epistemic successes (laboratory experiments, predictions, controlling phenomena, etc.), explanations become essential. Other potential skill-based achievements such as insights, skills to operate with physical models, or abilities to grasp mathematical models intuitively, all require communicating epistemic results. These again are conceptually coached and often require the presence of explanations both in publication and in inter-subjective communication. Finally, how much of “knowledge-how” non-conceptual intuitions and skills are needed on day-to-day basis within a lab or field research is an empirical matter, for which armchair arguments can provide very little insights.

question is: What does it mean for an explanation to be objectively correct?

To say that an explanation is “objective”, is to say that an explanation is somehow available in an invariant form to people. This we hope is easy to see. Typically, *explanations are answers to explanatory why-questions*.

Together, the why-question and its answer form a miniature dialogical drama. Therefore, explanations can be seen as discursive artefacts. Epistemic subjects ask a “why-question” and receive an answer. The answer and the question together form the “*script*” of this epistemic drama. Often this drama is played by two epistemic actors – the explanation seeker and the explanation giver. However, explanations can also appear in a monologue, as a part of a personal quest for understanding. This does not negate the discursive (and thus objective) feature of explanations. For, when we seek an explanation by ourselves, we often play the same dialogical drama of providing explanations (explanation giving) to ourselves and evaluating them (explanation seeking). This is not a particularly novel idea – van Fraassen’s (1980) account of explanatory pragmatics is based on this *in situ* dialogical nature of explanations; even more broadly, Catarina Dutilh Novaes (2020) proposes a similar account for the origin of deduction as well. Of course, the “*script*” of scientific explanations proper is often available to a broader audience (such as a scientific community).

Similarly to dialogues in dramas, explanations are not context independent. That is to say, explanations are not unrestricted “why-questions”. Contexts dictate explanatory questions and good answers. Again, recalling van Fraassen, even though explanations can be simple direct answers to why-questions, the context in which these why questions occur dictate what would count as appropriate answers. That is, an answer that provides the correct and the right amount of information.

As such, we can see explanation as defining a *specific scientific problem*. This problem contains:

1. A context in which the why-question occurs; and
2. The specific conceptual framing of the fact seeking explaining. Naturally, together the context and the framing of the why-question dictate the possibility space of potential answers. *The answer to the explanatory question, the explanans*, then counts as a solution to the problem, when it is one of the possible answers to the problem and that possible answer is “the right one”. Our next question is: What does it mean to have “a right explanation”?

As we said, we propose to view explanations as problem-solving activities. We believe that this offers a way to unify the different theories of explanations. Different cognitive problems and their contexts define different solutions, so similarly scientific problems permit different solutions as well. This can concern seeking causal explanations, trying to subsume the explanandum under a general law, etc.² Given that there are so many potential ways in which we can explain, how can we specify the conditions for “right explanations”?

Under our definition of explanatory understanding, we classified explanatory understanding as requiring *correct* explanations. Here perhaps the informed audience is already anticipating some well-known argument for or against explanatory pluralism. We however are not going to provide anything to that end.³

What the correctness of explanations means, for us, concerns the evaluation of explanatory information in terms of answers to explanation seeking problems. The idea here is that the specific context and the formulation of the explanatory problem already frames the potential solution within some of the boundaries of certain type of explanation. For instance, if I am asking: “Why is

2 In fact, such an approach to explanation has been sporadically discussed by Gary Hardcastle (n.d.) and in greater detail by Mantzavinos (2016).

3 One can easily see our account as pluralistic, and indeed we are sympathetic to explanatory pluralism, but we will have something neutral to say about it when we reach the case study.

the earth not flat?" in a physics class, I would be looking for a causal, or perhaps some kind of law-based explanation. If I am to ask the same question in a bible study group, the answer I anticipate would be different. This is to say, oftentimes the context and the framing of the explanatory problem already invoke a specific theory of explanation, with relevant background knowledge, so that we can construct and evaluate what would count as a correct explanation. Taking a hint from Khalifa (2017), we provide some conditions on what constitutes a correct explanation:

A correct explanation is a contextually appropriate, relevant answer to a why-question that abides by specific requirements including:

- (1) Structural requirements, provided by a relevant theory of explanation;
- (2) Informational requirements, provided by the context of inquiry along with a relevant theory of explanation;
- (3) Ontological requirements, provided by relevant theories of understanding.

The structural requirements for correct explanations are the formal requirements for the type of inference that the explanation instantiates. These we can freely borrow from the norms of "correct" explanations that each theory of explanation provides. For example, deductive explanations dictate the deductive type of explanatory structure for the inferences from the explanans to the explanandum. The formal requirements for the deduction include soundness, plus extra requirements for the premises as containing law-like generalizations, appropriately linking premises or auxiliary conditions, etc. A case for an incorrect explanation that fails such structural requirements can be an invalid deduction. For causal theories of explanations, the structure can take many forms, one is the form of counterfactual inferences. The formal requirements for them are these that define which counterfactuals point to the right causes, that bring about the effect of the explanandum. In this case, an incorrect explanation will be one that fails the structural requirements, by offering irrelevant causes.

These structural requirements for explanations work in tandem with *informational requirements* for the type and amount of explanatory information. The informational requirements for an appropriate explanation, aim to capture the context sensitivity of explanations. So given a specific explanatory question and its context of occurrence, the information that the answer contains can be *just enough*; or else *too much*, *too little*, or *irrelevant*.

When the explanatory information is *sufficient*, that is, just enough, the explanation is *correct*. Otherwise, it can be *incorrect* in being *excessively informative* when the information is too much, *incomplete* when the information is too little, or *inadequate* when the information is irrelevant.

This can be shown for causal explanations with an example. Consider the following explanations:

(A) All salt dissolves in water, because CH: salt is sodium chloride, and sodium has loosely bound outer electrons and is therefore highly reactive.

(B) All salt dissolves in water, because CH and STR: a mass of granular soluble substances dissolves more quickly than a mass of cubes of the same substance.

(C) I bought salt cubes, because they were at a discount.

When the relative question is: "Why does salt as a substance dissolve in water?", A would be sufficient, B excessive, and C inadequate. If on the other hand the question is: "Why does a cube of this substance dissolve more slowly than a heap with the same mass?", A would be incomplete, B sufficient, and C inadequate. Finally for the mundane problem: "Why do we have this salt that dissolves so slowly?", A would be inadequate, B incomplete, and C sufficient.

So now we have two types of requirements for explanations. You can say that the correct explanation for something is structurally correct while also sufficiently informative. Too much, too little, or irrelevant explanatory information all undermines the correctness of an explanation.

However, here some might have questions about the incorrectness of an explanation when the information is *too much*. For example, proponents of the ontic view of explanations, who claim that

explanations are out there in the world, or realists who believe in the ideal of complete explanatory texts of nature, might claim that excessively informative explanations should count as correct as well. After all, a complete causal description of the world contains the details of each specific causal explanation. The problem “Why doesn’t my car start?” then is simply a fragment of the complete causal history of the universe.

We, as mere mortals, treat excessively informative explanations as *incorrect*. The issue here is that we humans are not gods, and ideal explanatory texts serve little epistemic purpose to limited cognitive beings. We think that excessively informative explanations constitute an obstacle to one’s understanding, as one would often be unable to cut the information at the right place, due to lack of abilities to process the whole, ideal explanation. The explanatory problem then would remain unsolved. Another way to think about this idea is that even if we have a complete explanatory text, this text still needs to be “cut” at the right place in order to function as an answer to a specific question. This “right place” could be defined only if we already have the sufficiently informative explanation at hand. Trying to uncover this explanation would then mean that we have to construct it, so we are essentially at square one. After all an ideal explanatory text, would provide the same answer to every single explanatory seeking question – the complete answer of the causal history of the universe. With this we are no better off, than simply looking for the answer by engaging with the world directly.

All these considerations make us believe that excessively informative explanations do not extend our understanding.

Now we move on to ontological requirements. They do not concern how the information is structured within an explanation, nor the amount of such information. Instead, they are about how we evaluate this information as being *true*. This problem lies at the heart of the factivity debate in the epistemology and philosophy of science.

Two positions in the debate argue about the criteria for judging the truthfulness of explanatory information. On the one hand, factivists subscribe to a correspondence theory, as the right tool for evaluating the ontological status of explanatory information. They argue that the makers of the information in the explanans are facts. Non-factive accounts argue that instead of facts, the truth makers can be pragmatic. Such accounts often appeal to effectiveness in promoting predictions or practical applications.

Today we don’t have time for an exhaustive account of the factivity debate; moreover, we believe that this debate has to a large degree been reduced to the yet unsolved problem of scientific realism vs instrumentalism.⁴

To stay focused on understanding, here we transcend the factivity debate by relying on a neutral account of understanding by Khalifa (2017, 2023). It suggests a form of “explanatory voluntarism” and claims that both factivists and non-factivists often agree on core explanatory cases in the literature, therefore they both have ontological criteria for correctness that largely overlap for contemporary scientific explanations.

Having the ontological, informational, and structural norms in place, we can easily give the conditions for the “objective correctness” of an explanation. For instance, an explanation does not provide understanding, if it does not abide by structural or ontological norms, or if it is informationally irrelevant. Relative to the informational requirement alone, if the explanation is insufficiently or excessively informative, it can provide some understanding. However strictly speaking, such explanations are objectively incorrect, as they fail to solve the explanatory seeking

4 A meta-analysis of the debate would easily notice that both factivists and non-factivists often do not provide original arguments for their positions but rely on well-known arguments of realists and anti-realists, such as the “pessimistic meta-induction”, the “no-miracle argument”, and the “structural continuity thesis”.

question. In fact, as we said, proponents of partial or excessive (complete) explanations, can judge them only against an available, informatively sufficient explanation, from which they can judge such projects as partially or excessively informative.

With these considerations in mind about what constitutes a “correct” explanation, we can turn our attention to *the subjective dimension* of understanding. In our definition, this subjective dimension aims to capture the features of an epistemic agent, so she can construct or grasp the correct explanation. Once we engage with the subjective dimension of understanding, our central claim that explanatory understanding can be seen as a type of problem-solving activity really comes into light.

There are two routes to understanding through seeking explanations: A.) the explanation is provided, so the explanation seeker can analyse and assess it as correct; and B.) the explanation seeker must arrive at the correct explanation by herself. Whether or not the explanation is provided or discovered, both can be seen as explanatory problem-solving activities. That is to say, in all cases of explanatory understanding, achieving understanding can be seen as problem-solving cognitive tasks. As such, we believe that the analysis of understanding can be significantly enriched by the currently available theories of problem solving from cognitive science.

Cognitive science differentiates between two types of problems: A.) problems that require a step-by-step, *analytic solution*; and B.) problems that require an *insightful* or creative solution. At first sight, these two types of cognitive activities neatly capture the two clear-cut cases of understanding mentioned above: A.) the analytic solution captures the case where an explanation is introduced to the explanation seeker, and she has the whole information needed to analyse and assess it as correct; and B.) the insightful solution captures the case where the explanation seeker must discover a correct explanation, when no previous explanation is available or known.

With these clear-cut cases in mind, it is also worth noting that scientific understanding, similar to everyday problem-solving tasks, is typically a mix of analytic and insightful solutions.

For instance, available explanations can require insights as well, when they are presented to an epistemic subject who is unfamiliar with the concepts and inferential structures of the explanations. By the same token, when creative explanatory solutions are called for, the explanation seeker might also need to engage with an analytic, step-by-step cognitive task of assessing her creative ideas.

Thus, the subjective grasping or construction of a correct explanation involves the relevant background knowledge, abilities and skills to either analytically evaluate an explanation, or reach an insight.

There is another important piece of empirical information that is highly relevant to our study. The cognitive science on problem solving has also shown that, the two modes of problem solving are often accompanied by two distinct kinds of phenomenology. Participants in experiments have reported a warming, fuzzy feeling of gradually increased satisfaction when reaching an analytic solution. For insightful or creative solutions, there is typically an “aha!” feeling of sudden excitement when discovering the correct solution (see for example, Kounios and Beeman, 2014).

This brings us back to the analytic literature on understanding. The analytic armchair analysis of understanding has oversimplified the phenomenal side of understanding, as restricted to just the “aha!” feeling of excitement, when one arrives at an insight to the right explanation or grasps a new one. Moreover, the philosophical literature has also converged on the idea that the subjective feeling of understanding is neither necessary nor sufficient for understanding (for a summary see Baumberger et al., 2017).

We on the other hand are more inclined to first carefully analyze the relevant experimental results (coming from cognitive science of problem solving), before reaching any evaluation of the phenomenology. We thus see that the literature on cognitive science can present a much more nuanced picture of both the epistemic successes and failures of understanding. For instance, as we

shall see in a moment, we think that phenomenological differences between subjects is an important factor in the cases of misunderstanding. But to introduce that point, we must place side by side the analysis of cognitive science of problem solving and the literature on understanding.

We have already noted that both the philosophical and the cognitive science literature mark the existence of a phenomenal side of understanding – the “aha!” moment of insight, when a cognitive problem is solved or when understanding is reached. The divergence appears, when philosophers try to analyse the reliability of the “aha!” moment of understanding, from the armchair. Most philosophers claim that the phenomenology of understanding is an unreliable indicator of actual understanding. They also dispute the consistent presence of any “feeling” in cases of understanding.

The cognitive science on problem solving paints a much more nuanced picture. Firstly, there is some good evidence that insight solutions are correct more often than analytic ones (Salvi et al., 2016). And secondly in experiments, false insights can be triggered by semantic priming or misleading hints (Ammalainen and Moroshkina 2021; Grimmer et al. 2022).

Together these studies show that, the “aha!” feeling of an insight is reliable, when the background knowledge relevant to solving the problem is itself not misleading or false. A similar parallel then can be drawn to understanding – the feeling of insight is a reliable factor of understanding, when the background information relevant to solving the explanatory problem is itself not misleading.

This parallel between problem solving as a general cognitive activity and understanding, can be extended further. Cognitive scientists have also addressed the problem of what impairs insight. They have shown that mental sets can either facilitate or impair arriving at a correct solution (Schultz and Searleman, 2022). Mental sets are the tendency of people to apply previously successful solutions to problems that are similar to the problem at hand. This also means that the satisfying feeling of problem solving reinforces typical ways of arriving at a given solution.

Naturally, if creating or grasping an explanation is taken as a cognitive task, we have no reason to doubt that similar cognitive mechanisms would be in play. That is, for us the success of understanding, along with its specific positive phenomenology, can be seen as forming specific epistemic habits, much like mental sets. Previous positive experiences would reinforce the habit of seeking similar solutions to solve novel problems. Similarly, the phenomenology of understanding can also bias the epistemic agent to assert an explanation that conforms more easily with previously accepted explanations.

Obviously then, like the way “semantic priming” by false information can bias people to arrive at a false insight, previously accepted bad explanations might prime the epistemic subject to arrive at a feeling of understanding that is misleading. In fact, when discussing the experiments that trigger false insight, cognitive scientists note that false insight could be the culprit making some of us susceptible to conspiracies and propaganda through misinformation (Grimmer et al. 2022). The only difference is that, the studies on semantic priming show that such epistemic failures do not result from the positive phenomenology of insight or the cognitive mechanisms that generate insights. The epistemic failures instead largely depend on the presence of unchecked misleading background information on which the mechanisms of insight operate.

This leads us to believe that false understanding can happen regardless of one’s intelligence or some specific cognitive abilities. It largely depends on her exposure to certain explanatory practices. More interestingly, for us, this can also lead the epistemic agent to *reject an otherwise correct explanation in favour of an explanation that resembles previously accepted explanations*.

To capture this idea, we label the subjective tendency of the habitual employment of previously proven to be successful, explanatory strategies, as *epistemic inclinations*. The previously successful explanatory strategies that are powering epistemic inclinations appeal to the ontological, informational, and structural requirements for correct explanations. In explanatory problem-solving,

they offer a way to frame the explanation-seeking problems and dictate the satisfying answers.

We thus expand on our minimal definition of explanatory understanding mentioned earlier. A more precise definition of understanding is:

The cognitive achievement that occurs from the subjective grasping or construction of a correct explanation, that requires specific cognitive skills and abilities, is often accompanied by positive phenomenology, and leads to the development of relevant epistemic inclinations.

With this definition in mind, we can finally characterize the negative phenomena of understanding: *lack of understanding* and *misunderstanding*. The literature on understanding often brushes away the negative hastily as lack of correct explanations or necessary cognitive skills and abilities (such as Khalifa, 2013). Here we see this tendency as too restricted and limited. For conceptual clarity, we characterize this often-noticed negative phenomena of understanding as “lack of understanding” which concerns epistemic failures that result from a lack of explanation, from an incorrect explanation, or from a lack of necessary cognitive skills and abilities.

This brings us to the point, that the literature on understanding has so far failed to clarify a potentially interesting and important failure of understanding – that of *misunderstanding*.

We believe that it is possible for one to reject an otherwise correct explanation, even when one has the relevant skills and abilities to grasp it. This can happen when such an explanation does not trigger a positive phenomenology, due to different epistemic inclinations. We call such failures to arrive at understanding, *misunderstanding*.

To illustrate misunderstanding with a case study, we focus on the dispute between proponents of distinctively mathematical explanations and causal explanations in philosophy of science. A simple example from the debate is: A parent who has twenty-three strawberries and three children cannot distribute the strawberries evenly without cutting any (strawberries!) (Lange, 2013). Proponents of distinctively mathematical explanations claim that a correct explanation could be: “Because 23 is non-divisible evenly by three and this mathematical fact constrains the possibility of dividing the strawberries evenly” (such as Lange, 2013). While the proponents of causal explanations propose that a correct explanation should be: “Because the physical system is causally constrained in such a way that both the facts of having 23 strawberries and 3 children hold, the fact that 23 is non-divisible evenly by three explains the failure of the parent.” (such as Bangu, 2021)

Our take on this debate is that, there is misunderstanding between two parties due to different epistemic inclinations. They have different ways to frame the explanatory problems and to arrive at answers. Right at the onset, we would like to emphasize that, the outcome of this debate is irrelevant to our argument. It is beside the point for us whether one or both parties win, namely whether one or both explanations are correct. The important point is that, in the debate, there is at least one party that rejects an otherwise correct explanation, even though they can have the cognitive abilities and skills to grasp the correct explanation. That is, if it turns out that no mathematical explanation can be correct, then its proponents fail to accept causal explanations as correct and thus has a misunderstanding. It is the same for proponents of causal explanations misunderstanding mathematical explanations. However, if both mathematical and causal explanations can be correct, then the two camps misunderstand each other. Either way, our analysis of misunderstanding stands.

We here clarify that a theory characterizing misunderstanding is not a theory of explanation. It is beyond its scope to judge which is correct for the dispute between ontic and mathematical accounts of explanations. Our perspective is to use it to analyse misunderstanding which occurs between the two parties due to different epistemic inclinations.

We rule out the situation that their disagreement is due to a lack of abilities or skills. Because,

after all, given such a simple case of explanation, it is not plausible that one's rejecting the correct explanation is due to lack of abilities and skills to grasp it. This line of reasoning leaves us the option of diverging epistemic inclinations. Let's provide more details of this divergence.

The mathematical camp asks the question "Why does the parent fail to divide 23 by 3 (strawberries) evenly?" and answers with "Because 23 is non-divisible evenly by three and this mathematical fact constrains the possibility of dividing the strawberries evenly". A mathematically inclined explanation seeker has the epistemic tendency to frame the facts with a mathematical structure, and is satisfied by the mathematical deduction as a correct explanation.

The causal camp asks the question "Why does the parent fail to physically divide 23 by 3 strawberries evenly?" and answers with "Because the physical system is causally constrained in such a way that both the facts of having 23 strawberries and 3 children hold, the fact that 23 is non-divisible evenly by three explains the failure of the parent." A causally inclined explanation seeker has the epistemic tendency to frame the facts with an ontic structure, and is satisfied by the causal constraints in a correct explanation.

Again, however the debate ends, one can conclude that at least one party has misunderstood what the potential framing of the problem could be. That is to say, if causal accounts are correct, then the mathematical framing of the explanandum is not. Thus, philosophers defending distinctly mathematical explanations misunderstand that causal explanations can be the only genuine way by which scientific explanation proceeds. Similarly, if mathematical accounts turn out to be correct, then proponents of causal accounts misunderstand, that there is more than one way a genuine scientific problem can be framed and given an explanation.

Here for simplicity, we have framed the diverging epistemic inclinations between two camps in terms of different structural requirements – causal or mathematical. But there can be more. Earlier, we mentioned how structural requirements work in conjunction with informational requirements. The debate here is rich enough to extend to that as well.

Some arguments in the debate have evolved into analysing the informativeness of the explanatory answers themselves. For instance, Lange (2018) seems to claim that, an otherwise simple and straightforward mathematical explanation would become excessively informative with the addition of causal information.

From the causal camp, Bangu (2021) and Bueno and Colyvan (2011) claim that explanations become insufficiently informative with only mathematical information. So it seems that both parties endorse different informational requirements.

Here we won't further unpack the debate but hypothesize that, both camps have the necessary cognitive abilities and skills to grasp what their opponents see as correct explanations. In this case, the reason for denying their opponent's correct explanations might be a divergence in their epistemic inclinations. That is to say, a mathematically inclined explanation seeker is biased to attribute explanatory value to mathematical explanations over others, due to her epistemic inclination for framing the explanatory questions and answers mathematically. Same for the causal camp. We further hypothesize that this normative appraisal might have something to do with the phenomenology of understanding. Their respective positions might be due to the reinforcement of previous positive phenomenal experiences of typically seeking mathematical or causal explanations to arrive at understanding. This then leads to the failure to appreciate that, perhaps mathematical framing alone cannot explain facts in the world, or that discovering causes is not the only way in which we can understand why certain events happened.

A final remark on this short overview of the debate between proponents of causal and mathematical explanations. It seems that we can find empirical justification for the epistemic inclinations of both parties, from the psychology of explanatory understanding (Keil 2006). In a review on explanations and understanding, Frank Keil notes that causality plays a central role in the

way we tend to explain facts; but also that simple, compressed information is preferable (in the way, for instance, mathematical explanations provide unified, essential representations of explananda). Following these remarks, it seems to us that both causal and mathematical explanations rely on genuine cognitive intuitions. This leads us to think that these intuitions have not evolved from overly complex philosophical or metaphysical views, but instead from epistemic inclinations developed from specific educational and everyday explanatory practices and habits.

To conclude, it might seem to the audience that we have painted a rather grim picture of the potential disagreements concerning different explanatory practices. However, this need not be the case. Although we developed the notion of epistemic inclination, in relation to mental sets and mental rigidity, these cognitive features admit of degrees and are subject to change. We defined epistemic inclinations with the positive phenomenology from a successful problem solving. In scientific contexts, this success obviously depends on one's abilities and skills, the quality of one's background knowledge, but also on how the resulting explanatory output is met by the scientific community. As such, explicitness and open-mindedness are key to resolving debates and misunderstanding. Even though misunderstanding is sometimes inevitable, it does not entail that a rigid dogmatism is the norm. Instead with sufficient explicitness, conflicts between different explanatory practices can be resolved.

Discussion

Audience: You distinguish misunderstanding from lack of understanding. So the question is whether misunderstanding is a distinct kind of lack of understanding?

Haomiao Yu: No. Lack of understanding is more about whether you have or grasp a correct explanation, while misunderstanding is more about your attitude towards other explanations against your requirements for explanations, regardless of whether you already have a correct explanation for a specific phenomenon.

Stefan Petkov: Whenever we have a pluralistic scenario with more than one correct explanation, there could be a failure to enrich one's understanding, by an explanation that covers some other aspects of the explanandum, or frames it in a different way. This can happen when people already have some explanations about the fact, and these explanations are correct. They have formed epistemic inclinations based on them and might resist any new ways to see the explanandum and to accept novel explanations. This does not mean that they have a total lack of understanding, but it means that by misunderstanding they fail to enrich their understanding. You can also say, that they have a "lack of understanding" relative to a specific framing of the explanandum, and a specific explanatory answer. But that would miss the important point. That is, in such a case the person has failed to grasp a new explanation, not because that person lacks intelligence, or some epistemic skill, but because that person is biased from her previous experiences of understanding. This bias has obstructed her to accept novel ways to see the explanandum, of accepting novel problems and new solutions.

Audience: I'm interested in whether your account can make it sufficient to just have the phenomenology of understanding to show real understanding.

Haomiao Yu: As a matter of fact, we are working on a full-fledged phenomenal account of understanding. I think our current account is too moderate. Stay tuned!

Stefan Petkov: We believe that epistemically relevant phenomenology is actually an overlooked factor in the way we philosophers see how knowledge and understanding occur. We tend to separate the presence of any kind of epistemically relevant emotions such as curiosity, boredom, or even resistance to new information. We sometimes get angry at complexity or at what is contradictory to what we currently believe. All these emotions actually play a part in the way knowledge and understanding are formed.

But we philosophers often separate such feelings from what we see as “rational”. We see them as subjective, whilst knowledge and understanding are somehow objective universal realities.

This is hardly the case in actual every day or even scientific practice; in fact, I believe that it’s not the case for analytic philosophers as well. If one is to look closely, we should see that epistemically relevant phenomenology plays a big part in forming our opinions, adopting new ones, or assessing our own discoveries. After all, “an intuition” on which studying *a priori* cases depends, is a phenomenal state.

This work on explanations is the first step. It only shows that the phenomenal side of our cognition is a highly influential factor to the way we understand, the way we grasp or discover explanations. We hopefully illustrated clearly that “rationality” (analyzing structural, ontological, informational features of explanations) goes hand in hand with a phenomenal feeling of insight, acceptance, discovery, or relief that one has solved a complex problem, or some negative feelings such as a sense of dread from overly cumbersome explanations, etc. We think that such feelings are not always so easily separable from what we philosophers tend to focus on.

Audience: How do the objective and subjective components of understanding come together?

Stefan Petkov: These are actually only analytically separable components. In practice, our understanding is naturally dynamic. It is perhaps useful if I give you an example from my own experience. I was engaged with a philosophical problem. It was way back when I was working on unification. I was trying to build up on Kitcher’s analysis and tried to solve the asymmetry problem of explanations, which his account is accused of failing to do. Initially it was impossible, I couldn’t come up with an idea how to accommodate the fact that explanatory unification is asymmetrical with a deduction based on symmetrical laws. That is in classical mechanics for instance, you can transform the equation of the law to derive each of the variables from the others. This means that premises from the explanandum and premises from the explanans can sometimes shift places so long as the general law remains intact. I thought about it, I thought, I was really worked up with that problem. One night I had a dream. I was in a philosophy hall of my old university. There was a lecture going on and the lecturer was holding an empty frame of a painting. I woke up and I thought that it’s not the deductive derivation which actually explains; it’s the conceptual relations, which can be symmetrical or asymmetrical, and are theoretically defined that do the explanatory heavy lifting. So, I came up with the idea of “conceptual framework”.

An explanatory argument simply exemplifies these conceptual relations, just like a frame defines the borders of the painting within. So the generality of an explanation depends on the way the concepts within an explanatory arguments are positioned and related one to the other. This, so to speak sets the “boarders” of an explanatory pattern, what the explanation can potentially capture. So the concepts and their relations are the framework, and the potential paintings, are the possible explananda, permitted by the concepts.

But the details of that philosophical work don’t matter. What matters is the way the discovery of “explanatory unification” has occurred to me. You see when we actually try to understand something new, when we try to discover something, everything plays a part. Thinking about the problem even when the problem is purely conceptual is not necessarily only conceptual, we can

imagine visual symbols, build any kind of mental model. In fact anything goes.

However, when the solution appears *we tend to and must* clear up the clutter. We should separate the process of discovery from its product. In this case we separate how we have arrived at the explanation – the product, from our evaluation of that product; from our thinking if that explanation is actually the correct one. When I am trying to discover a new explanation there could be half-baked solutions, unclear ideas, false starts, all of that plays a part. When we seek a novel explanation, we are not only relying on previous skills and abilities, we develop them, become better at them, discover new ways of thinking, etc. The separation between objective and subjective components of understanding especially when we deal with a problem that concerns a single person seeking an explanation for himself, is just an analytical tool.

On that account, skill-based theories of understanding, and theories of understanding that claim that there is something beyond explanations in relation to understanding, are on the right track. But they go only half-way. Whenever we are concerned with scientific knowledge, the end point, the final product that we are to evaluate, share with others, compare, etc., I believe, always takes the form of an explanation. In that sense I believe that explanations have a primary function for scientific understanding. How we arrive at these explanations on the other hand is not something we can easily generalize over.

Audience: Are the components involved in misunderstanding all cognitively subjective, and lack of understanding cognitively objective?

Haomiao Yu: This is an interesting way to put it. Misunderstanding is about one's requirements for explanations against other's requirements for explanations. It is more interpersonally "subjective", if we have use "the analytic tool" to frame it, as Stefan pointed out just now. And lack of understanding seems more individually "objective"?

Audience: I was curious about epistemic inclination. It sounds like in the ideal explanatory context, your inclination attends to certain parts of explanatory information, and mine to another part. It seems almost as if we, due to our epistemic inclinations, tend to see the phenomenon differently, as different things. Then we can disagree about it, because we see it differently.

Stefan Petkov: You can say that. We were in a sense going for this kind of relativism, although I believe it is too strong. If this point is pursued to its limit, it becomes quite impossible to solve scientific disputes. This is after all not the case. There are clear situations where scientists begin with a disagreement, then discover that one explanatory theory was wrong, or that what has initially seemed to be in contradiction can be synthesized into a unified theory. I once did some research on a by-now historical predator–prey modelling; ecologists were initially in disagreement over how to represent predator intake of prey in their mathematical models. Both parties had some empirical support for their views. It took about ten years for them to realize that the models were actually compatible and to build a unified representation of population dynamics. But at the end of the day the empirical domain and analysis of how their different explanatory models worked, both played a role in reaching an agreement. Maybe one way to say this is that given different epistemic background, people see different aspects of the same phenomenon; these aspects might seem contradictory at first, but later on one can discover that they are actually complementary.

Audience: What's the difference between your view and de Regt's view? It seems to me that the notion of epistemic inclination is quite similar to de Regt's contextual understanding.

Stefan Petkov: We think de Regt's theory is skill-based. It implies that if one lacks skills, then one lacks understanding. But our case study presents a situation that is certainly not about lack of skills, but about epistemic inclinations and positive phenomenology. You can try to say that these inclinations are just skills and abilities. But that would make the concept of "skill" in his account too inclusive, too general. One can play with such general concepts, make them seem that they already imply something, but like this analytic precision is lost. We think that we discovered something interesting. Firstly, we analysed misunderstanding as a distinct failure. Secondly, we showed that it's not about skills and abilities, but the phenomenology that plays a part in the way we arrive or fail to arrive at an understanding.

Audience: Is pluralism right or wrong in your view?

Stefan Petkov: Personally, I am a pluralist about explanations. But this particular idea – the notion of misunderstanding is itself neutral to any pluralist or monist position. We believe that this is a strong point of our theory. It is quite possible that you are a pluralist and misunderstand one kind of explanation, after all to be a pluralist doesn't mean that you accept every explanation as a good one. Same goes for a monist. Let's take it for granted that there is only one kind of scientific explanations – causal ones. It is still possible that you prefer some type of causal explanation, say a counterfactual one, and that explanation is not as good for some explananda. This I believe is particularly true for historical narratives. A lot of historiography is causal. But counterfactuals are definitely not the norm in history. In fact, historians tend to call counterfactual history "historical fiction". Yet some believe that counterfactuals are better, they can in some cases reject a perfectly good historical narrative, just because it does not conform to their theory of counterfactuals.

Audience: But at the mathematical level one can argue that pluralism is wrong, and insist on a monist position according to one's mathematical inclination.

Haomiao Yu: This is likely. There still can be two choices for a mathematically inclined person. If she is rigid and monist, she cannot develop another inclination. If she is not rigid, she can accept a pluralist position and embrace a causal explanation. Holding one inclination should not exclude the possibility of another inclination, although we argue that bias most likely happens and often leads to misunderstanding.

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