Can Scientific Understanding Be Achieved Without Explanation?

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The relationship between scientific understanding and explanation has traditionally been regarded as conceptually inseparable. Many philosophers have treated explanation not merely as a means to understanding, but as constitutive of it. On this orthodox view, to understand a phenomenon scientifically is to possess a correct explanation of it, typically articulated as causal mechanisms, natural laws, or theoretical unification. This assumption underpins classical models of explanation, like Hempel's deductive-nomological account (Hempel & Oppenheim, 1948), and broader epistemological conceptions concerning the aims of science. Understanding is, simply, the cognitive achievement that explanation affords.

However, recent developments in epistemology and the philosophy of science have problematised this alignment. Scholars like Catherine Elgin, Michael Strevens, and Stephen Grimm argue that although explanation often plays a central role, it is not universally required for understanding. Drawing on examples involving idealised models, computer simulations, and heuristic reasoning, they suggest that scientists may sometimes attain genuine understanding even in the absence of full or correct explanatory frameworks. Furthermore, intuitive or experiential forms of 'grasp', as well as predictive and counterfactual competence, may in certain contexts suffice for understanding.

In this essay, I defend a nuanced version of this dissenting view. While acknowledging that explanation remains foundational within many scientific contexts, I argue that under specific epistemic conditions – like in domains characterised by complexity, abstraction, or computational opacity – understanding can arise independently of complete or literal explanation. Through conceptual analysis and attention to formal structures, including counterfactual dependence and epistemic reliability, I contend that the relationship between explanation and understanding is contingent instead of constitutive. Understanding, I propose, is a more flexible, pluralistic, and context-sensitive epistemic achievement than orthodox accounts typically allow.

I. Traditional Accounts: Explanation as Constitutive of Understanding

The traditional position in the philosophy of science maintains that explanation is not merely beneficial but is constitutive of scientific understanding. To understand a phenomenon is to grasp why it occurs, and that 'why' is supplied by a satisfactory explanation.

Carl Hempel's deductive-nomological (D-N) model represents a canonical articulation of this perspective. On this model, an event *E* is explained by deducing it from general laws and specific initial conditions, according to the following structure:

$$L_1, L_2, \ldots, L_n, C_1, C_2, \ldots, C_n \vdash E$$

Understanding, consists in recognising that *E* follows logically from a set of laws and conditions – that is, in locating *E* within a wider nomological system.

Stephen Grimm (2006) further develops this conception by arguing that understanding involves "seeing how things hang together" (p. 517). It differs from mere propositional knowledge by requiring a systematic integration of facts within a coherent explanatory framework. Understanding is holistic and structural.

Michael Strevens (2013) offers a refinement by advancing a causal theory of explanation. He proposes that to understand *E* is to identify those causes which are explanatorily relevant – that is, the factors which make a difference to whether or not *E* occurs. While not using the term, his framework supports a kind of 'causal economy', according to which a minimal subset *K* of causes suffices for explaining *E*:

$$\forall x\, (K(x) \rightarrow E(x))$$ [1]

This formulation underscores the importance of counterfactual dependence: to understand *E* is to know what would occur if elements of *K* were altered.

In summary, both the D-N and causal models portray explanation as the epistemic structure that underwrites genuine understanding. According to the traditional view, without such logical or causal scaffolding, what may appear to be understanding is, in fact, epistemically illusory.

[1] For all x, if x is a member of the set *K*, then x is a cause of *E* (i.e., x leads to *E*)

II. Challenges to the Constitutive Thesis

Although the traditional view closely links scientific understanding with explanation – often treating them as conceptually equivalent – recent philosophers have argued that this alignment is not necessary. One of the most influential among them is Catherine Elgin, whose *True Enough* (2017) challenges the assumption that both truth and explanation are jointly required for understanding.

Elgin draws attention to the widespread use of idealisations and simplifications in scientific modelling. The ideal gas law, $PV = nRT$, assumes physically implausible conditions like point particles and the absence of intermolecular forces. Yet the model remains central to thermodynamics, owing to its predictive success and theoretical utility. These models, she argues, are epistemically fruitful despite being literally false.

According to Elgin, what renders a model valuable is not strict correspondence with reality, but rather its epistemic acceptability – that is, its capacity to support inference, representation, and justification. Even if:

$\neg \forall x\, (M(x) \leftrightarrow P(x))$,[2]

meaning that the model *M* is not extensionally equivalent to the phenomenon *P*, understanding *U(P)* may still be achieved provided that:

$Coherent(M) \wedge PracticallyReliable(M) \vdash U(P)$

Here, internal coherence and practical reliability form the basis for attributing understanding, thereby decoupling it from traditional explanatory requirements. The cognitive value of such models lies not in their truth, but in their ability to organise complex information, guide reasoning, and facilitate scientific inquiry.

This reconceptualisation has far-reaching philosophical implications. Understanding, on Elgin's account, becomes an active and constructive epistemic achievement, shaped by abstraction, modelling, and imaginative engagement. The boundary between explanation and

[2] It is not the case that, for all x, the model *M* and the phenomenon *P* are equivalent.

representation is thus blurred: what matters is not whether a representation mirrors reality, but whether it renders a phenomenon intelligible and investigable.

Elgin thus invites a re-evaluation of what constitutes scientific understanding, as well as the role of models within our epistemic practices. Rather than viewing models as deficient approximations of explanatory truth, we might more productively regard them as epistemic tools, designed to make complex aspects of the world cognitively accessible and manageable.

Not all philosophers accept the view that understanding can be separated from knowledge or explanation. Paulina Sliwa (2015), presents a contrasting position by defending a reductionist account, according to which understanding simply reduces to knowledge. On her view, to understand why something is the case is no more than to know why it is the case. The same applies to understanding that or what. Sliwa challenges alleged counterexamples in which an individual is said to understand without knowing, arguing that such claims are either pragmatically infelicitous or conceptually incoherent. For instance, statements like "Jane understands why the hepatitis medication is effective, but she does not know why it's effective" (p. 61) are, according to Sliwa, semantically contradictory. In her view, our resistance to such claims the fact that understanding entails the relevant knowledge. Thus, from this perspective, cases of supposed understanding without explanation or truth are best interpreted as misunderstandings of what epistemic success consists in, instead of as genuine instances of a distinct cognitive state.

A further objection comes from the view that understanding is not merely compatible with knowledge, but constituted by it. Sliwa (2015) argues that attributions of understanding without corresponding knowledge are pragmatically infelicitous or conceptually incoherent. For example, to say that 'she understands why *p*, but does not know why *p*' is, on her analysis, contradictory. If this analysis is correct, then the notion of understanding without explanation or truth becomes unstable, and much of the recent pluralist enthusiasm may be misplaced.

III. Grasp and Non-Explanatory Understanding

David Bourget's (2024) phenomenal theory of grasping challenges the assumption that understanding must necessarily be grounded in propositional knowledge or articulated explanation. Instead, Bourget contends that understanding frequently emerges as a form of experiential acquaintance with the structural or modal features of a phenomenon – what he terms *grasping*.

One achieves understanding not by formulating laws or theories, but by cognitively apprehending how a system behaves or 'fits together'. This grasp is typically holistic, intuitive, and non-discursive. Bourget expresses this formally:

$Grasp(P) \vdash U(P)$

That is, the cognitive grasp of a phenomenon *P* can yield understanding even in the absence of an explicit explanation.

This conception is clearly relevant to scientific practice. For instance, a climate scientist working with ensemble simulations may develop an operational understanding of system dynamics through engagement with model outputs, even where the underlying causal mechanisms remain opaque due to system complexity. Similarly, in machine learning, users often interact effectively with "black-box" models – like neural networks – that produce accurate predictions without providing interpretable explanatory mechanisms:

$Success(Prediction) \wedge Sensitivity(InputVariations) \vdash U'(P)$

In such cases, users may attain a form of practical understanding *(U')* based on pattern sensitivity and behavioural familiarity, rather than explanatory transparency.

This phenomenon resonates with the epistemology of skill and know-how: just as one can competently navigate a city or play a musical instrument without articulating the underlying principles, so too can one attain understanding through embedded practical engagement. Such non-explanatory understanding is particularly salient in fields characterised by complexity, emergence, or computational opacity.

Crucially, Bourget's account does not reject the value of explanation. Rather, it demonstrates that grasp-based understanding constitutes a legitimate – and often indispensable – cognitive strategy. It thereby opens the way for a pluralist epistemology, wherein explanation remains important, but is no longer seen as the exclusive route to understanding.

One influential objection to non-explanatory accounts is that genuine understanding requires a form of epistemic control – an ability to use and apply information in a normatively guided way. Alison Hills (2009) argues that understanding involves a kind of cognitive autonomy: the agent must not merely know that something is the case, but also grasp why it is so. Without explanatory content, she contends, we risk collapsing understanding into passive belief or mere familiarity. On this view, explanation is not optional but essential to any robust conception of epistemic achievement.[3]

IV. Counterarguments: Strevens on Counterfactual Sensitivity

Whilst non-explanatory accounts of understanding emphasise intuition, modelling, or predictive success, Strevens (2013) argues that counterfactual sensitivity is essential for genuine scientific understanding. Mere prediction or pattern recognition, he contends, is epistemically inert unless it is accompanied by an appreciation of how outcomes would vary under changes in relevant conditions.

Formally, Strevens maintains that an agent *A* understands a phenomenon *E* only if:

$$\forall x, y\ (x \neq y \rightarrow A(Know(E_x \nrightarrow E_y))))$$[4]

That is, *A* must grasp how *E* depends upon changes in antecedent conditions – an ability which reflects modal robustness instead of mere empirical fit.

For example, to understand why a bridge collapsed, it is insufficient merely to predict its failure; one must grasp that had the load been distributed differently, the collapse might not have occurred. Such sensitivity to counterfactual scenarios is, for Strevens, what elevates cognition from reliable output to genuine explanatory insight.

Strevens acknowledges that scientific models are often idealised or simplified. However, he insists that their epistemic value depends upon their capacity to track core causal dependencies. Simulations or heuristic models confer understanding only if they embody an implicit explanatory structure – what may be thought of as a ‘causal skeleton’: a minimal framework that captures the difference-making relationships underlying the phenomenon. By contrast,

[3] While Hills develops this argument in the context of moral epistemology, particularly in relation to the limits of moral testimony, her emphasis on cognitive autonomy and explanatory grasp lends itself to broader applications in theories of understanding.

[4] For all values x and y, if x is not equal to y, then agent *A* knows that event *E* would be different in scenario x than in scenario y.

predictive models that fail to reflect genuine causal relations, like certain black-box algorithms, may guide action but lack epistemic depth.

This point resonates with Grimm's (2014) account of understanding as a form of causal knowledge, in which the explanatory value of a model rests not merely on its predictive power, but on its ability to reveal the underlying causal structures of the phenomena it represents.

In summary, Strevens presents understanding as a normative epistemic achievement, one that demands alignment with the world's counterfactual structure. Without this alignment, we risk mistaking mere instrumental fluency for genuine understanding, thereby collapsing the crucial distinction between science and mere engineering.

Contemporary developments in machine learning illustrate how high-performance models can foster an illusion of understanding. As Peter Lipton (2009) argues, genuine understanding requires more than the ability to predict outcomes – it requires access to the explanatory structure that makes sense of those outcomes. In cases where agents cannot identify why the system behaves as it does, any apparent understanding remains epistemically shallow, grounded in tacit interaction rather than transparent explanation.

V. Pluralism About Understanding

Challenges to the constitutive link between explanation and understanding have given rise to a pluralist conception, according to which scientific understanding can emerge through diverse epistemic strategies, each suited to particular domains and contexts.

Both Elgin and Grimm advocate this pluralist perspective. [5] Grimm (2024) contrasts scientific understanding, which typically involves grasping causal or nomological structures, with humanistic understanding, which arises through the construction of coherent narratives. In historical inquiry, for example, intelligibility is achieved not by appeal to universal laws, but by rendering events meaningful through human agency and context. On this view, narrative coherence can suffice for understanding, even in the absence of mechanistic explanation.

[5] Elgin does not explicitly use the term "narrative coherence", but she argues that understanding in fields such as art, literature, and history often depends on forms of coherence – metaphorical, exemplificatory, or interpretive – rather than on traditional explanatory structures. See Elgin (2017), *True Enough*.

Importantly, pluralism extends beyond the humanities. Within science itself, understanding can arise through idealised models, analogies, and thought experiments – as exemplified by Galileo's investigations of falling bodies or Einstein's trains and clocks in the development of the special theory of relativity. Such representations need not be literally true provided that they advance epistemic aims like unification, simplicity, and explanatory depth.

Further support for pluralism comes from Kareem Khalifa's (2017) causal nexus model, articulated in what he terms *The Nexus Principle* (p. 6), which holds that understanding a phenomenon *P* consists in situating it within an appropriate causal network *N*, even if a full articulation of *N* is unavailable:

$$\exists \mathit{CausalNetwork}\ N\ (\mathit{Includes}(P) \wedge \mathit{RevealsDependencies}(N)) \vdash U(P)$$

On this account, understanding arises from qualitatively mapping relevant dependencies rather than from providing a complete formal exposition.

Pluralism thus affirms that intelligibility, predictive power, and explanatory utility can be achieved through a variety of representational forms. It resists epistemic relativism by upholding normative criteria – such as coherence, explanatory relevance, and context-sensitivity – while acknowledging that no single explanatory strategy suffices across all domains of inquiry.

This pluralistic stance reflects the richness of epistemic life. Understanding is not monolithic, but a multi-dimensional achievement – realised differently across disciplines such as physics, biology, and history. Its flexibility is not a weakness but a strength: an essential feature of the adaptability and progress of human inquiry.

If understanding can be attained through any form of representational success – such as predictive accuracy or intuitive modelling – there is a risk that the concept becomes overly inclusive and epistemically diluted. Grimm (2014) argues that what distinguishes understanding from mere belief or practical know-how is its structural explanatory power. When explanation is no longer treated as a requirement, there is a danger of conflating instrumental competence with genuine epistemic achievement. This concern underpins a more conservative position that retains explanation as the central criterion separating understanding from other cognitive states.

VI. Case Study: Quantum Mechanics

Quantum mechanics provides a paradigmatic case in which predictive success far outpaces explanatory consensus. At its core lies the Born Rule:

$$P(M) = |\Psi|^2$$

which assigns probabilities to measurement outcomes M based on the wave function Ψ. This principle underwrites extraordinarily precise predictions across a wide range of phenomena, from atomic decay to superconductivity (Maudlin, 2019).

Despite its empirical adequacy, the ontological status of Ψ remains deeply contested. Competing interpretations like Copenhagen, Many-Worlds, and Bohmian mechanics offer radically divergent metaphysical accounts of quantum reality (Maudlin, 2019). This lack of consensus reveals a disjunction between *knowing how* and *knowing why*: scientists are able to predict and manipulate quantum systems with remarkable reliability, yet without agreement on a coherent explanatory framework.

Philosophers have thus described quantum theory as supporting a form of practical or operational understanding. That is, even in the absence of unified explanation, physicists achieve reliable, interventionist competence:

$$PredictiveSuccess(\Psi) \land EffectiveIntervention(\Psi) \vdash U'(M)$$

This form of practical understanding challenges the traditional assumption that explanation is necessary for epistemic achievement. As Strevens (2013) argues, full understanding ideally involves counterfactual sensitivity; yet the quantum case suggests that functional mastery can precede – or even bypass – such explanatory depth.

The case of quantum mechanics thus lends support to pluralist theories of understanding (Elgin, 2017; Grimm, 2024), which hold that scientific progress and intelligibility may be attainable through models and formalisms whose explanatory credentials remain unresolved. Nonetheless, the persistent philosophical effort to interpret Ψ indicates that explanation continues to function as a regulative ideal within scientific inquiry.

VII. Conclusion

Explanation has long been regarded as the principal route to scientific understanding. Yet both historical precedent and contemporary philosophical analysis suggest a more nuanced picture. While explanation remains central and epistemically privileged, it is not invariably required for understanding. Idealised models, computer simulations, intuitive forms of grasp, and predictive heuristics demonstrate that, in certain contexts, scientists may attain genuine understanding without recourse to complete or fully articulated explanations.

This asymmetry may be formalised as follows:

$$\textit{Explanation} \vdash U(P), \quad \textit{but} \quad \neg(U(P) \vdash \textit{Explanation})$$

That is, although explanation is sufficient to confer understanding of a phenomenon *P*, understanding may nonetheless arise in its absence.

However, this insight should not be taken to imply that explanation ought to be marginalised. Even when understanding is initially achieved through non-explanatory means, the aspiration to explain persists as a regulative ideal within scientific practice. Explanation deepens, stabilises, and systematises understanding – it transforms practical efficacy into integrated theoretical insight.

A philosophically adequate account of scientific understanding must therefore strike a careful balance. It should acknowledge the diversity of epistemic practices – modelling, idealisation, simulation, and intuition – whilst maintaining explanation as a normative touchstone. Epistemic pluralism need not entail relativism; rather, it reflects a recognition of the variety of scientific goals and methodological constraints.

One way to articulate this balance is through what might be termed *explanatory gravity*. [6] This concept captures the tendency of scientific inquiry to gravitate toward explanation, even when other forms of understanding may temporarily suffice. Much like a gravitational field exerts an invisible pull, the explanatory ideal orients inquiry toward causal and structural elucidation. It

[6] The term 'explanatory gravity' is introduced here to characterise a normative tendency within scientific inquiry: even when understanding arises through non-explanatory means, scientific practice is often drawn – gravitationally, so to speak – towards causal or structural explanation. The notion captures explanation's enduring role not merely as an epistemic tool, but as a regulative force guiding the integration, refinement, and deepening of understanding across contexts.

underwrites our sense of epistemic progress, shapes standards of success, and mediates the transition from operational familiarity to deeper intelligibility.

Explanatory gravity thus helps distinguish between surface and substantive understanding. Where models and heuristics yield predictive accuracy, they afford a kind of practical grasp. But when scientists seek to uncover why such tools succeed – what underlying mechanisms or dependencies they reflect – explanation reasserts itself as the deeper epistemic aim. Ultimately, the task is not to dethrone explanation, but to reposition it within a broader, more context-sensitive conception of understanding – one that accommodates the heterogeneous strategies of science without abandoning its unifying ideals. Such a view does greater justice both to the practice of inquiry and to the nature of epistemic achievement itself.

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