The Logic of Proof of Concept Research

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Proof of Concept Research (PoCR) is a prevalent facet of scientific inquiry, yet its epistemic features remain poorly understood. While novelty has been highlighted as a key characteristic, projectability—understood as the likelihood of being applicable to a broader range of contexts—is another. This study endeavours to construct a formal model that elucidates the implicit ampliative reasoning inherent in PoCR. Our model hinges on probability assumptions for target objects to simultaneously exhibit three properties: one that is a defining characteristic of these target objects; a second that is desired of them and whose demonstration is the empirical aim of PoCR; and a third that is promised in the background. Depending on assumptions about when these properties jointly obtain, we delineate paradigmatic, alternative, and tangential modes of reasoning. This classification and associated decision tree unveil distinct argumentative strategies that, despite not being deductively valid, may be employed to motivate PoCR and justify subsequent inferences upon successful proof of concept demonstration. The model and decision tree together provide a framework with which to better understand the general structure of widely used inferences in PoCR, and with which researchers and evaluators can more precisely design and assess PoCR projects.

1. Introduction

The term ‘proof of concept’ (PoC) is commonly employed in technological and engineering spheres to denote the development of a preliminary prototype, often used to showcase a new functionality for purposes such as patent applications or securing additional funding for further development, manufacturing and commercialization. In medical research and Phase II clinical trials, PoC signifies the demonstration of clinical efficacy of a novel drug through pilot studies and is a critical step towards larger Phase III trials and regulatory approval. The term is used in a variety of scientific contexts, alongside synonyms such as ‘proof of principle’ or ‘proof of feasibility’. A cursory exploration on Google Scholar reveals a plethora of PoC works: from molecular DNA recorders in molecular biology (Choi et al. 2022) to miniaturized spectrometers in

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opto-electronics (Yoon et al. 2022), including climate change negotiation strategies in economics (Schmidt and Ockenfels 2021) and the integration of machine learning in chemistry (Singh et al. 2020). The ubiquitous use of the term prompts a critical inquiry into the typical epistemic characteristics of proof of concept research (PoCR).

Beyond its inherent risk, PoCR appears to stand out for the promises it is seen to unlock. For instance, PoC research on electricity-producing nanochannels (Logan and Elimelech 2012), by aiming to demonstrate in the lab that nanochannels can harness salinity gradients, is actually fuelling high hopes for large-scale energy production. Examining PoC research on biofuel-producing cyanobacteria, Catherine Kendig characterizes PoC research as ‘projectable’ (2016, p. 740) and identifies two key projectability promises: extending the PoC to similar objects (for example, using engineered cyanobacteria to produce other substances upon successful PoC demonstration that cyanobacteria could be made to produce biofuels), and applying PoCR methods to analogous contexts (for example, engineering other chassis organisms for similar purposes upon successful PoC demonstration). Similarly, investigating modelling practices in theoretical evolutionary genetics, Steve Elliott (2021) underscores the importance of projectability claims in PoCR and proposes a framework for evaluating PoC success that includes the development of prototypes, PoC demonstrations, and the use of heuristics in *post facto* arguments to justify research pursuit, including projectability arguments.

Building on these insights, we analyse the underlying reasoning in PoCR, arguing that a characteristic form of ampliative reasoning is at work not only for justifying projectability claims and further *post facto* research, but also for designing and motivating PoCR itself. Our model clarifies key argument patterns by focusing on the interplay of three properties: a defining characteristic (for example, nanochannels), a desired property whose demonstration is the objective of the PoC (for example, electricity production), and a background property implicitly promised (for example, scalability). By assessing the likelihood of these properties co-occurring through simplifying assumptions, PoCR employs non-deductive reasoning to establish their joint plausibility (for example, large-scale electricity generation via nanochannels). This model provides a framework for identifying the assumptions and inferences typically shaping PoCR reasoning and associated claims.

Depending on prioritized assumptions, we identify paradigmatic, alternative, and tangential modes of reasoning that can be made explicit to first motivate PoCR and undertake a PoC demonstration, but also to justify further ampliative inferences such as projectability upon successful PoC demonstration. Illustrating these patterns of reasoning with a case study from energy research—electricity-producing nanochannels—we demonstrate the model's capacity to elucidate the intricate reasoning used in PoCR. While the proposed model and associated decision tree can qualitatively reconstruct various instances of PoCR, we do not claim that they uniquely depict PoCR: their value lies in explicating the complex and potentially obscure patterns of reasoning in PoCR, thereby offering a framework for designing and evaluating these research endeavours.

In what follows, §2 introduces the notion of PoCR. In §3, we present our model and its underlying assumptions, followed by a description of the paradigmatic reasoning typically employed in PoCR. §4 explores alternative and tangential modes of PoCR reasoning. §5 examines how assumption prioritization influences the choice of specific modes of reasoning. §6 delves into how projectability and novelty are accommodated in the model, also drawing comparisons with analogical reasoning.

2. Proof of concept research

Research on nanochannels designed for harvesting 'blue energy' (Logan and Elimelech 2012) is a good example of PoCR. This innovative idea revolves around the use of selective membranes composed of nanochannels to harness salinity gradients at the interface between river water and seawater, thereby generating electricity. Recent advancements in nanochannel technology, demonstrating high selectivity for specific molecular species, suggest the potential for exploiting osmotic pressure differences created by salinity gradients to produce electrical current (Wu et al. 2023).

As we are told, 'proof-of-concept studies on single nanopores demonstrated that the power density reaches up to 10^3 to 10^6 W.m^{-2}' (Gao et al. 2019, p. 1), showcasing the feasibility of generating exceptional power densities (Siria et al. 2013). Extrapolating these outcomes to much larger scales—with membranes of square metres rather than fractions of square micrometres—opens the possibility for establishing industrial-scale plants at estuaries to meet global electricity demand. The inherent risks of failure associated with scaling up this technology are mitigated by the potential of offering a renewable energy source to address the global carbon and energy crisis.

The rationale for undertaking such PoCR can be qualitatively reconstructed as follows: (i) theoretical grounds suggest nanochannels could enable high-density electricity production; (ii) large-scale electricity production is worthwhile given a socio-economic context of high electricity demand, and also realistic given precedents like hydropower and nuclear plants; (iii) building plant-sized nanochannel membranes, though challenging, is considered feasible with sufficient efforts; (iv) therefore, demonstrating nanochannels' high-density electricity production in the lab strengthens the plausibility of large-scale electricity production, justifying the pursuit of PoCR.

This non-deductively valid reasoning obviously cannot guarantee the realization of the target conclusion. Several premisses involve hypothetical elements, such as the successful creation of electricity-producing nanochannels and their scalability. Even a conclusive PoC experiment in the laboratory cannot guarantee the feasibility of constructing large electricity-producing plants based on nanochannel membranes. Retrospectively, while PoC experiments have corroborated the capability of certain nanochannels to produce high-density electricity, it still remains uncertain today whether scaling up these implementations to larger membranes will proportionally extrapolate power density since coupling effects may induce non-linear scaling and bottlenecks in transport phenomena at larger scales (Gao et al. 2019).

Regardless of its ultimate success or failure, this example illustrates how PoCR is embedded within an intricate justificatory scheme, utilizing a complex set of properties and assumptions. PoCR first involves demonstrating that a specific implementation of certain objects with property X (in this case, nanochannels) can also possess property Y (producing high-density electricity). The prior inclination to believe this will be the case arises from theoretical assumptions about the capabilities or properties of these objects.[1]

PoCR is further motivated by an ampliative reasoning about an additional property Z (for example, scalability or large dimension).[2] This introduces two additional assumptions: an assumption about the feasibility of objects that exhibit X to also exhibit Z (for example, the

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[1] For nanochannels, the PoC demonstration is experimental and concerns material systems (as in Kendig 2016), but a PoC demonstration can also be about some abstract entity (for example, a model, calculus or algorithm that is shown to work through a simulation, a method) (as in Elliott 2021). We use the term 'object' to cover both.

[2] Scalability, or the capacity to be made in large dimensions, is often mentioned as a key desired property in PoCR, but many other properties of interest are also frequently found, including extended scope, timespan or duration, complexification, robustness to changes in environmental conditions, and so on, as well as reduction in cost, which matters most for technological research outcomes.

possibility of nanochannel membranes to be made in large dimensions); and an assumption about the possibility of objects exhibiting Y to also exhibit Z (for example, the desired large scale of electricity-producing objects).

Motivation for PoCR stems from the argument that, since (i) there are good reasons to believe that objects with property X also possess property Y, since (ii) there are other good reasons to believe that objects with property Y can also possess property Z, and since (iii) there are yet other good reasons to believe that objects with property X can also have property Z, then, (iv) there are good reasons to believe that there exist objects that can simultaneously exhibit all three properties X, Y and Z (for example, nanochannel membranes of large dimensions capable of producing high-density electricity). Consequently, PoCR is deemed worthy of pursuit, potentially leading to a successful PoC demonstration. In turn, a successful PoC demonstration, while only showing that objects with X may also exhibit Y, fuels projectability and increases the likelihood assigned to the existence of objects exhibiting all three properties X, Y and Z.

This three-property-based pattern of reasoning is exemplified in Kendig's (2016) synthetic biology case with biofuel-producing cyanobacteria: the PoC consists in demonstrating that cyanobacteria organisms (X) can be engineered to produce biofuel (Y); in this context, a successful PoC demonstration is taken as evidence raising the probability that cyanobacteria are good chassis organisms for producing a broad range of desirable biomolecules (Z). Similarly, Elliott's (2021) example in theoretical evolutionary genetics follows the same logic. There, the PoC concerns abstract models and consists in showing, through simulations, that a specific mechanistic set of models of pleiotropic genetic inheritance in a given population (X = being such models) can lead to evolutionary lesser fit hybrids and speciation (Y = having as outcome lesser fit hybrids and speciation). A successful simulation of such models will indicate a successful PoC demonstration and will be taken as evidence that they are promising for explaining speciation in other populations (Z = concerning other populations).

Examples of PoCR across various scientific domains involve similar—and often implicit—inferences that mobilize three central properties. In molecular biology, for instance, PoCR about molecular DNA recorders concerns strands of nucleic acids (X) used to record some specific types of information (Y), with the hope of being leveraged for recording more varied and numerous sets of biological events of interest at the cellular level together with their temporal sequences (Z)

(Shipman et al. 2016; Frieda et al. 2017; Choi et al. 2022). In optoelectronics, a miniaturized spectrometer PoC shows that a single detector with a unique tunable van der Waals junction (X) can be made to reconstruct a simple two-colour image (Y), thereby fuelling the hope that arrays of such spectrometers might reconstruct larger images with broader bandwidth, paving the way to ultraminiaturized computational spectrometers (Z) (Wang et al. 2019; Yoon et al. 2022). In chemical informatics, research on the identification of asymmetric catalysts via machine learning leads to fitting a random forest model on a training set of parameters characterizing a subset of chiral catalyst families (X); this random forest model proves accurate in predicting catalysts of the test set (Y), which leads to increased confidence in the capability of random forest models to be trained for identifying broader sets of asymmetric catalysts (Z) (Singh et al. 2020). In economics applied to climate change negotiations, a PoC experiment involving human subjects participating in a public good game corroborates game-theoretic findings that negotiating a uniform common commitment (X) better promotes cooperation (Y) than negotiating individual commitments (as in the Paris Agreement) or complex common commitments (as in the Kyoto Protocol); in turn, this raises confidence about the possibility to promote cooperation when actually renegotiating future climate change international agreements (Z) (Schmidt and Ockenfels 2021).

3. The triadic model of proof of concept research

As just shown, PoCR often relies on ampliative arguments that, while logically invalid, offer compelling reasons to believe in the simultaneous achievability of specific desired properties. To qualitatively reconstruct these arguments, we introduce a 'triadic model' grounded on three properties and their pairwise probabilistic assessment of simultaneously obtaining. First, a property X that characterizes a specific set of objects under investigation (for example, being in nanochannels). Second, a property Y that is of interest (for example, producing electricity) and that is specifically targeted by the PoC. Third, an additional property Z also of interest (for example, being scalable or of large dimensions), which is typically the focus of projectability (Fig. 1).

Although these three properties are sought together, assumptions are initially made about their likelihood to be realized in pairs due to limited empirical knowledge about objects exhibiting X. PoCR is typically driven by a theory or theoretical elements according to which

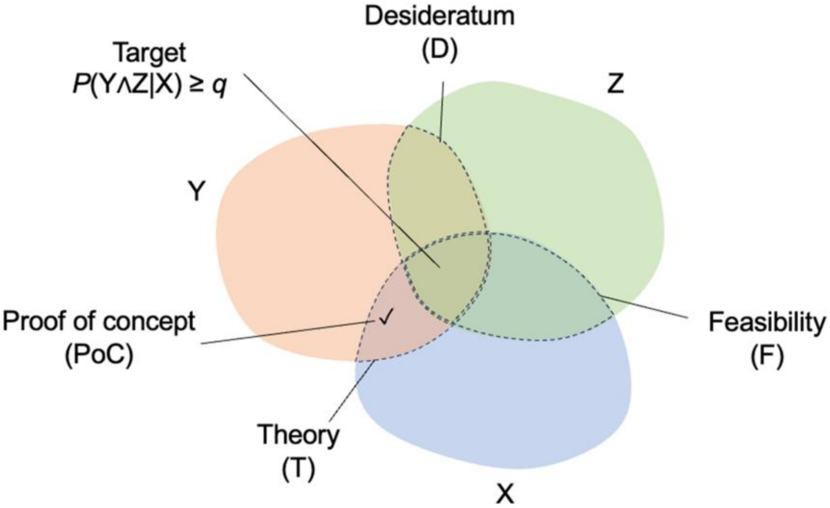

Fig. 1. *PoCR and its assumptions.* Research concerns objects with property X (e.g. consisting of nanochannels). A theory assumption (T) gives good reasons to think that such objects X can also have property Y (e.g. producing electricity). Furthermore, a feasibility assumption (F) gives good reasons to think that objects with property X can also have property Z (e.g. being scalable or large), while a third assumption (D) concerns a broad desideratum about the existence of objects with both Y and Z properties (e.g. large objects that produce electricity). The hope is that objects with property X can also have both properties Y and Z, which is to say that the intersection of all three properties is non-empty (the PoC target: $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$ where q is an acceptable probability given the PoC context). The PoC itself consists in showing, through a demonstration, that there indeed exists X-objects that also have Y (that is, $P(\mathrm{Y} \mid \mathrm{X}) \geq p$ where p is an acceptable probability given the PoC context).

objects with X should also exhibit Y. However, before a successful PoC demonstration, the theory has little support. At the same time, for the PoC to be meaningful, one should also have good reasons to think that objects with X should be capable of exhibiting Z, and furthermore, that properties Y and Z can be combined. In our proposed model, the first assumption (T) concerns the theory that objects with X may also exhibit Y, or in other words, that X and Y can be realized simultaneously (formally, this is to assert that $\mathrm{X} \wedge \mathrm{Y}$ is non-empty and reasonably populated as per Figure 1, or similarly that $P(\mathrm{Y} \mid \mathrm{X}) \geq p$ where $p \in \,]0,1]$ and has a value corresponding to moderate-to-high risk in science).[3] (T) gives

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[3] When asked to rate the riskiness of their research on a scale from 1 to 10, scientists report an average score of 5, with fewer than 10% rating it at 8, indicating particularly high risk (Myers et al. 2023). In our case, a probability $p < 0.5$ may represent a moderate-to-high risk endeavour, though our argument does not depend on any specific value. Throughout, we use p, p', p'', q across multiple assumptions to denote acceptable probabilities given assumed risk in PoCR.

good reasons to believe that the PoC is realizable (that is, the PoC demonstration will be successful). In our example, (T) claims that nanochannels can generate electricity, which the PoC experiment will test.

The second assumption (F), denoted ‘feasibility’, captures confidence in objects with property X possibly exhibiting property Z (formally, $P(\mathrm{Z} \mid \mathrm{X}) \geq p'$, which is to say, $\mathrm{X} \wedge \mathrm{Z}$ is non-empty and reasonably populated). In our example, (F) claims that it should be feasible to build large membranes of nanochannels, disregarding their ability to produce electricity in the first place. Having good reasons to believe (F) may be based on actual realizations of $\mathrm{X} \wedge \mathrm{Z}$ without Y or the belief that such realizations will be possible in the future.

The third assumption (D) concerns the ultimate ‘desideratum’ of the target objects, expressing confidence in the existence of objects exhibiting both properties Y and Z (that is, $\mathrm{Y} \wedge \mathrm{Z}$ non-empty and reasonably populated), independently of whether these objects exhibit X. This desideratum typically follows from a pre-existing normative goal according to which jointly realizing Y and Z (for example, building large electricity-producing systems) is worth pursuing. (D) is equivalent to assuming that $P(\mathrm{Y} \mid \mathrm{Z}) \geq p''$ or, conversely, $P(\mathrm{Z} \mid \mathrm{Y}) \geq p''$, depending on whether we assume first the existence of objects that realize Z or of objects that realize Y. This assumption can be based on observed realizations with objects not possessing X, or the compatibility of Y and Z until proven otherwise. In our example, the probability of electricity-making objects (Y) that are large (Z) is not null since such objects exist (for example, hydropower dams or nuclear power plants), so the desideratum is not unrealistic. In high-risk research, whether $\mathrm{Y} \wedge \mathrm{Z}$ is non-empty and reasonably populated is truly unknown yet extremely desirable, so it is worth pursuing as if it were true.

To summarize, the triadic model includes three assumptions about X, Y and Z:

$P(\mathrm{Y}|\mathrm{X}) \geq p$ (T – Theory assumption)
$P(\mathrm{Z}|\mathrm{X}) \geq p'$ (F – Feasibility assumption)
$P(\mathrm{Y}|\mathrm{Z}) \geq p''$ or $P(\mathrm{Z}|\mathrm{Y}) \geq p''$ (D – Desideratum assumption)

The value of PoCR lies in the high uncertainty of implementing Y with X, even given (T). This uncertainty may arise from lack of support in favour of the theory behind (T), lack of precision, or excessive idealization. The PoC may even be chosen as research objective because (T)

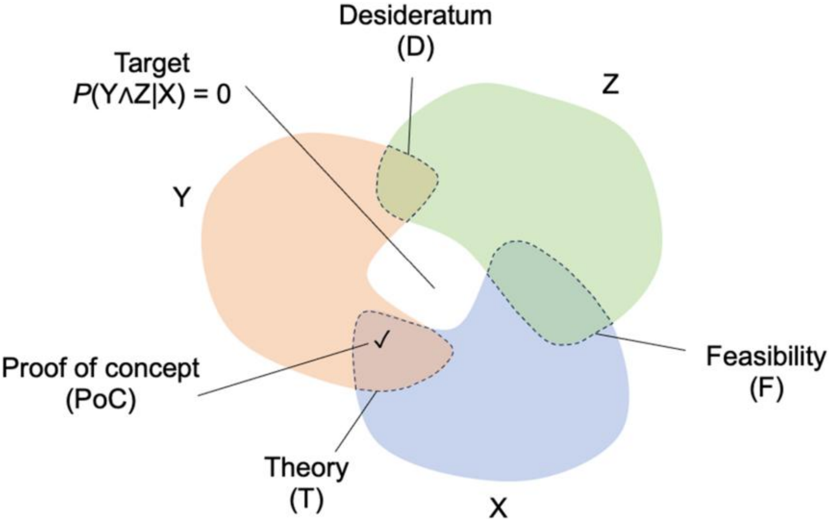

Fig. 2. *PoCR without any attainable solution*. The settings are similar to Figure 1, except that the three properties cannot be exhibited all at once: $P(Y \wedge Z \mid X) = 0$. A successful PoC demonstration increases the support of (T), yet this is so in a context where no object ultimately exists that would have all three properties.

is the most uncertain assumption compared to (F) and (D). Realizing a PoC demonstration corroborates (T) and resolves the perceived main bottleneck given current knowledge.[4]

While actual PoCR focuses on demonstrating that X-objects can exhibit Y independently of Z, the motivation for such research stems from an intricate ampliative reasoning that weaves together all three properties and all three assumptions (this reasoning is further unpacked in §§4 and 5). However, even if a successful PoC demonstration provides an instance of X-objects capable of Y, corroborating (T), and even if there are good reasons to believe that objects with X can have Z (F), and that Y and Z are compatible (D), it does not follow that adding Z to X still allows Y (for example, whether nanochannels, once made in large dimensions, still produce electricity at high density). The joint truth of (T), (F) and (D) is necessary but not sufficient (Fig. 2),

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[4] Moving from PoCR to more robust research programmes through iterations of implementations and theory, researchers may end up defining the property X so well that (T) always applies (that is, all X-type objects possess Y). Then, feasibility (F) alone implies the final target and (D) is redundant. This is not so when the theory assumption (T) still has little support.

highlighting that PoCR reasoning is not deductively valid despite its centrality to justifying research pursuit and PoC projectability.

Ultimately, motivation for PoCR relies on the size of the intersection of X, Y and Z, that is, the value of $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$. Ideally, one would like to know that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ is relatively high, signifying the existence of numerous X-objects capable of simultaneously exhibiting Y and Z. In a less ideal scenario, having good reasons to believe that reaching the target is, if not highly likely, at least reasonably probable—that is, $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$—justifies further investigation of X-objects. The motivation for PoCR thus hinges minimally on assessing whether $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$. We now explore how this assessment can be accomplished.

4. Assessing the possibility of success

So far we have argued that motivation for PoCR depends on having good reasons to believe that at least some objects will exhibit three properties of interest depending on assumptions about their pairwise likelihood of obtaining. We now show how to precisely characterize these reasons as probability statements that can be assessed with the help of further assumptions about the relative behaviour of two properties given a third one (which we call assumptions of indifference). The starting point is to assess whether $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$. Note that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ can be decomposed in two symmetric ways, using the definition of conditional probability applied to $P(\mathrm{Z} \mid \mathrm{Y})$ (equation 1) or $P(\mathrm{Y} \mid \mathrm{Z})$ (equation 2) in a universe of discourse already conditioned on X:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) = P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}).P(\mathrm{Y}|\mathrm{X}) \tag{1}$$

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) = P(\mathrm{Y}|\mathrm{Z} \wedge \mathrm{X}).P(\mathrm{Z}|\mathrm{X}) \tag{2}$$

Whether one has good reasons to think that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$ then depends on further sets of assumptions about the terms of these decompositions. We identify four modes of reasoning that prioritize certain assumptions over others, and by so doing appear more or less paradigmatic as to what typically happens when motivating PoCR (Fig. 3).

4.1. Paradigmatic mode (I) of PoC reasoning

Commencing with equation (1), assumptions can be formulated to evaluate $P(\mathrm{Z} \mid \mathrm{Y} \wedge \mathrm{X})$. One plausible assumption is the indifference of property Z to property Y given property X. This is to say that the probability of X-objects exhibiting Z should remain the same whether they also have Y or not. The justification is that, so far, all objects that have

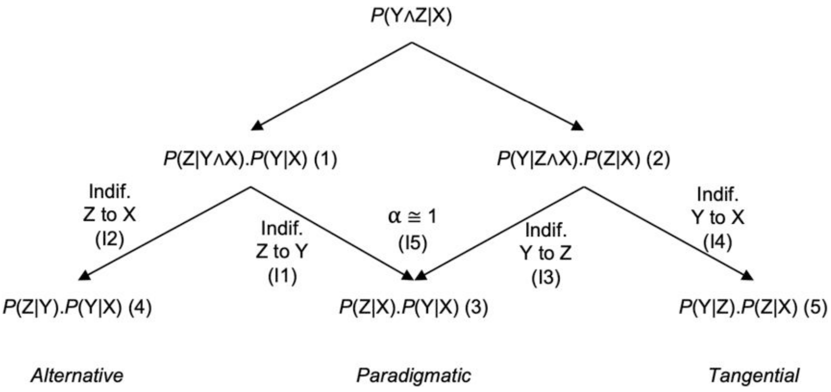

Fig. 3. *Alternative decompositions of* $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$. Assessing $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ can be done along four different paths, depending on which probability decomposition (1 or 2) is used and which indifference assumption (I1 to I4) is mobilized.

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been examined with property Z were indifferent to having property Y or not, so there is no reason to think it would be different for objects with property X: objects with property X should also be indifferent to Y when it comes to having Z. Having the property Y should not affect the probability of having property Z when one already has property X. This assumption can be expressed as:

$$P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}) \cong P(\mathrm{Z}|\mathrm{X}) \quad (\text{I1} - \text{Assumption of indifference of Z to Y given X})$$

In the nanochannel case, (I1) asserts that nanochannel systems (X) can be made large (Z) while preserving their property to produce electricity (Y) or not. The reason is that all the systems we have seen so far that could be made large (Z) were so while preserving their property to produce electricity (Y) or not, so this should be the same for nanochannel systems (X). From (1) and (I1), it follows that:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) \cong P(\mathrm{Z}|\mathrm{X}) \,.\, P(\mathrm{Y}|\mathrm{X}) \tag{3}$$

Yet the feasibility assumption (F) gives good reasons to believe that $P(\mathrm{Z} \mid \mathrm{X}) \geq p'$. Furthermore, (T) gives good reasons to believe that $P(\mathrm{Y} \mid \mathrm{X}) \geq p$, all the more so when the PoC is successful, since the demonstration provides support to our theories about X-objects being capable of exhibiting Y, and thereby increases $P(\mathrm{Y} \mid \mathrm{X})$. As a result, given (3), $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq p \,.\, p'$. Provided q is chosen such that $p \,.\, p' \geq q$, then $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$, meaning that there are sufficient reasons to think that the ultimate target is possible (though still risky).

This mode of reasoning—which we call mode (I)—captures a paradigmatic approach. Indeed, assumption (I1) makes sense, as it extrapolates from available knowledge about a wide range of objects with Z and with or without Y (think of all the systems that can be made in large dimensions, including those that can produce electricity such as hydropower dams and nuclear power plants) and assumes that what holds across all these objects should also hold for X-objects, for which not much is known (novel nanochannel membranes). (I1) therefore consists in a form of induction from what is known in general about objects with Y and Z, to the specific case of X-objects. Furthermore, the PoCR context is typically one in which there is strong confidence both in the feasibility assumption (F) and in the theory assumption (T), a successful PoC demonstration instilling further confidence in (T).

4.2. *Alternative mode of PoC reasoning*

Again, starting with equation (1), another assumption can be formulated: an assumption of indifference of property Z to property X given property Y (left-hand side of Figure 3). This is assuming that objects with property Y should be indifferent to X when it comes to having Z. The motivation for this alternative assumption may run as follows: so far, all the objects we have seen with property Z were indifferent to property X, so there is no reason to think it would be different for objects with property Y. So the probability of Y-objects having Z should remain the same whether they also have X or not: having the property X will not affect the probability of having property Z when one already has property Y. This assumption amounts to:

$$P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}) \cong P(\mathrm{Z}|\mathrm{Y}) \quad \text{(I2–Assumption of indifference of Z to X given Y)}$$

In the nanochannel case, (I2) suggests that electricity-producing systems (Y) that can be made large (Z) should remain so whether or not they are in nanochannels (X). The justification would be that all the systems we have seen so far that could be made large (Z) were so independently of whether they were made of nanochannels (X), so this should be the same for systems that produce electricity (Y). Note that, contrary to (I1), (I2) extrapolates from knowledge about X-objects, which is limited—despite motivations for assumptions (F) and (T)—given the context of PoCR (which precisely argues for more research on X-objects, notably with respect to property Y). (I2) is therefore less justified than (I1), yet still conceivable. From (1) and (I2), it follows that:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) \cong P(\mathrm{Z}|\mathrm{Y}) \,.\, P(\mathrm{Y}|\mathrm{X}) \tag{4}$$

While the desideratum assumption (D) gives good reasons to believe that $P(\mathrm{Z} \mid \mathrm{Y}) \geq p''$, the theory assumption (T) gives good reasons to believe that $P(\mathrm{Y} \mid \mathrm{X}) \geq p$, all the more so when the PoC is successful. As a result, given (4), there are good reasons to think that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq p.p''$ and the target is deemed to exist with sufficient likelihood provided q is chosen such that $p.p' \geq q$.

This mode of reasoning captures a non-paradigmatic yet possible mode of PoC reasoning. Similarly to the paradigmatic mode (I), this 'alternative' mode relies on confidence in (T) (which increases when the PoC is successfully demonstrated). Yet it also makes use of (I2), which is less justified than (I1), since (I2) relies on knowledge about X-objects, which is limited. Furthermore, this mode of reasoning relies on (D), which does not directly concern the X-objects under study, but a broader class of objects (those susceptible to exhibiting both Y and Z).

4.3. *Paradigmatic mode (II) of PoC reasoning*

Starting with equation (2), an assumption of indifference of property Y to property Z given property X can be formulated as the assumption that objects with property X should be indifferent to Z when it comes to having Y. Justification would be that, so far, all the objects we have seen with property Y were indifferent to property Z, so there is no reason to think it would be different for objects with property X. In other words, the probability of X-objects having Y should remain the same whether or not they also have Z:

$$P(\mathrm{Y}|\mathrm{Z} \wedge \mathrm{X}) \cong P(\mathrm{Y}|\mathrm{X})$$

$$\text{(I3 – Assumption of indifference of Y to Z given X)}$$

In the nanochannel case, (I3) posits that nanochannel systems (X) producing electricity (Y) should still produce electricity whether or not they can be made large (Z). This is justified if all the systems we have seen so far that could produce electricity (Y) could still do so independently of whether they could also be made large (Z); in that case, we would be inclined to assume that this should also hold for nanochannel systems (X). Similarly to (I1), (I3) relies on existing knowledge about a wide range of objects, and inductively assumes that what holds across all these objects should also hold for X-objects (for which not much is known). From (2) and (I3), it follows that:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) \cong P(\mathrm{Y}|\mathrm{X}).P(\mathrm{Z}|\mathrm{X}) \tag{3}$$

This mirrors the paradigmatic mode (I) of PoC reasoning. Here too, the feasibility assumption (F) and theory assumption (T) (corroborated by a successful PoC demonstration) give good reasons to believe that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$.

We can interpret this third mode of reasoning as another paradigmatic mode—mode (II)—of PoC reasoning. Indeed, (I3) is an assumption that inductively extrapolates from available knowledge about a wide range of objects with Y and Z to the specific case of X-objects under investigation. Mode (II) also relies on the feasibility assumption (F) and the theory assumption (T), for which there is typically strong confidence in the context of PoCR.

4.4. *Tangential mode*

Starting with equation (2) again, one can formulate an alternative assumption of indifference according to which having property Y should be indifferent to having property X given property Z (right-hand side of Figure 3):

$$P(\mathrm{Y}|\mathrm{Z} \wedge \mathrm{X}) \cong P(\mathrm{Y}|\mathrm{Z})$$
(I4 – Assumption of indifference of Y to X given Z)

Justification is more convoluted than in the previous case, but could go along the following lines: up until now, all the objects we have seen with property Y were indifferent to having property X or not, so there is no reason to think it would be different for objects with property Z; this is to say that having the property X should not affect the probability of having property Y when one already has property Z.

Illustrated with nanochannels, (I4) would state that large systems (Z) that can produce electricity (Y) should still produce electricity whether or not they are made of nanochannels (X); in other words, being made of nanochannels or not should not change the probability of large systems producing electricity. Why? Because all the systems we have seen that could produce electricity (Y) were indifferent to being made of nanochannels or not (X), and there is therefore no reason to think it would be different in particular for systems that can be made large (Z).[5]

As is apparent, (I4) is challenging to justify, notably when compared to (I1) or (I3). (I4) extrapolates from knowledge about X-objects with respect to property Y. Yet, given the context of PoCR (which precisely argues for more research on X-objects), knowledge about X-objects with respect to property Y is limited (despite assuming (T)). The justification basis for (I4) is therefore extremely thin.

We may also try to justify (I4) by a strong *ante facto* belief that property Z implies Y (at least with a high probability). In that case, it would be sufficient to produce X-objects that have Z to also have Y (at least with the same probability), as is the case with objects that do not have X. Yet justifying (I4) in this way undermines the very motivation for PoCR in the first place, since it implies that investigating whether objects that have X (without Z) can have Y is not needed, which is to say that neither assumption (T) nor a PoC demonstration are needed: the PoC would confirm what we already assume we know by (I4). From (2) and (I4) one obtains:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) \cong P(\mathrm{Y}|\mathrm{Z}) \,.\, P(\mathrm{Z}|\mathrm{X}) \tag{5}$$

While the desideratum assumption (D) gives good reasons to believe that $P(\mathrm{Y} \mid \mathrm{Z}) \geq p''$, the feasibility assumption (F) gives good reasons to believe that $P(\mathrm{Z} \mid \mathrm{X}) \geq p'$. As a result, $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq p'.p''$ and the target is deemed to exist with sufficient likelihood provided q is chosen such that $p'.p'' \geq q$.

Our interpretation here is that this case represents a possible yet far-fetched and quite tangential mode of reasoning that is on the brink of falling outside of what is usually conceived as proper PoC reasoning. Not only does (I4) rest on very slim evidence, but it also already presupposes what would be achieved by a successful PoC demonstration. Furthermore, the reasoning relies on assumptions (D) and (F), but not on (T). Overall, this set of assumptions does not establish the need for further research on X-objects. This mode of reasoning is akin to a

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[5] Maybe a more plausible illustration for this reasoning could be based on the following three properties: being in nanochannels (X), generating gravitational attraction (Y), and having a large mass (Z). In that case, (I4) would state that large-mass systems (Z) that can generate gravitational attraction (Y) should still generate gravitational attraction whether or not they are in nanochannels (X); in other words, being in nanochannels or not should not change the probability of large-mass systems producing gravitational attraction. Why? Because all the systems we have seen that could generate gravitational attraction (Y) were indifferent to being in nanochannels or not (X) and there is therefore no reason to think it would be different in particular for large-mass systems (Z).

form of in-principle reasoning, which is not using the PoC to generate new evidence (corroborating (T)) but only as a cover for what is asserted as already known.[6] As a result, arguing for a PoC experiment is extrinsic to the reasoning (possibly motivated by the wish to conceal this in-principle reasoning as a true experimental project).

4.5. *Paradigmatic mode (I+II)*

Despite mobilizing different assumptions (I1) and (I3), both paradigmatic modes (I) and (II) lead to the same breakdown of $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ as expression (3). The equivalence of the two assumptions can be understood by applying Bayes theorem to $P(\mathrm{Z} \mid \mathrm{Y} \wedge \mathrm{X})$ in the universe of discourse of X (that is, all conditioned on X). This results in

$P(\mathrm{Z} \mid \mathrm{Y} \wedge \mathrm{X}) = P(\mathrm{Y} \mid \mathrm{Z} \wedge \mathrm{X})\ .\ P(\mathrm{Z} \mid \mathrm{X})\ /\ P(\mathrm{Y} \mid \mathrm{X})$,

which can be rewritten as:

$$P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X})/P(\mathrm{Z}|\mathrm{X}) = P(\mathrm{Y}|\mathrm{Z} \wedge \mathrm{X})/P(\mathrm{Y}|\mathrm{X}) = \alpha \qquad (6)$$

From (1) and (6), but also similarly from (2) and (6), one gets:

$$P(\mathrm{Y} \wedge \mathrm{Z}|\mathrm{X}) = \alpha\,.\,P(\mathrm{Y}|\mathrm{X})\,.\,P(\mathrm{Z}|\mathrm{X}) \qquad (7)$$

Accordingly, assuming either (I1) or (I3) leads to the same results as assuming (I5) $\alpha \cong 1$: all three assumptions end up decomposing $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ as (3) (see Fig. 3). Assuming (I5) is like directly assuming that Y and Z are independent of each other given X. This is the null hypothesis when there is complete lack of data about how X affects Y and Z: we can assume that having X (or not) does not affect the probability of having Y and Z together when independent. In the nanochannel case, this is to say that being large and being capable of producing electricity can be thought of as two independent properties. (I5) amounts to assuming that being in nanochannels should not affect the probability of having the two properties jointly.

Endorsing (I5) results in the same assessment of $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ as the two complementary (and independently weaker) indifference assumptions (I1) and (I3). In that case again, both the feasibility assumption (F) and the theory assumption (T) (aided by the PoC demonstration) give good reasons to believe that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$. This is adopting an overarching mode (I+II) of PoC reasoning.

Note that in all modes of reasoning, assumptions (I1) through (I4) consist of approximations whereby one specific probability is replaced

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[6] Contrary to other modes of PoCR, the tangential mode is immune to a failure of PoC demonstration since it does not rely on (T).

by another. Yet, since the objective is only to assess whether $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$, weaker assumptions that only rely on inequalities—as in the following set (I1w) through (I4w)—are, strictly speaking, sufficient, and would lead to the same conclusions:

$$\text{If } P(\mathrm{Z}|\mathrm{X}) \geq p' \text{ then } P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}) \geq q \quad \text{(I1w)}$$

$$\text{If } P(\mathrm{Z}|\mathrm{Y}) \geq p'' \text{ then } P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}) \geq q \quad \text{(I2w)}$$

$$\text{If } P(\mathrm{Y}|\mathrm{X}) \geq p \text{ then } P(\mathrm{Z}|\mathrm{Y} \wedge \mathrm{X}) \geq q \quad \text{(I3w)}$$

$$\text{If } P(\mathrm{Y}|\mathrm{Z}) \geq p'' \text{ then } P(\mathrm{Y}|\mathrm{Z} \wedge \mathrm{X}) \geq q \quad \text{(I4w)}$$

These assumptions could be interpreted as denoting, not indifference of properties, but possibilities of exhibiting specific properties jointly. Compare (I1) and (I1w) in the nanochannel case. (I1) amounts to assuming that nanochannel systems (X) that can be made large (Z) should still be so whether or not they produce electricity (Y). (I1w) consists in assuming that, if it is possible to have electricity-producing (Y) systems that are large (Z), then it should be possible to have nanochannel (X) electricity-producing (Y) systems that are large (Z). In other words, making systems that make electricity in nanochannels does not alter the possibility of their being large.

Though these weaker assumptions are sufficient for the modes of reasoning we identified, their interpretation is possibly less intuitive compared to the probabilistic assumptions (I1) through (I4). The weaker assumptions, we believe, are therefore less likely to be mobilized in concrete instances of PoCR reasoning.

5. Why choose one mode of reasoning over another?

As we have seen, different modes of reasoning relying on different sets of assumptions can be mobilized to argue that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$ and motivate PoCR. We summarize them in Figure 4 as a decision tree. Choice of a mode of reasoning over another is certainly informed by practical matters, such as resources available to researchers. Yet ultimately, epistemic considerations about assumption plausibility and the role of successful PoC demonstrations affect the strength of any given mode and are of utmost importance in its choice.

Modes of reasoning grounded in the most solidly justified assumptions, given current knowledge, will indeed yield the most convincing estimation of whether $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$. Among the three assumptions of the triadic model, (T) and (F) likely boast the highest confidence (left-hand side of the decision tree, Figure 4). Indeed, both pertain to

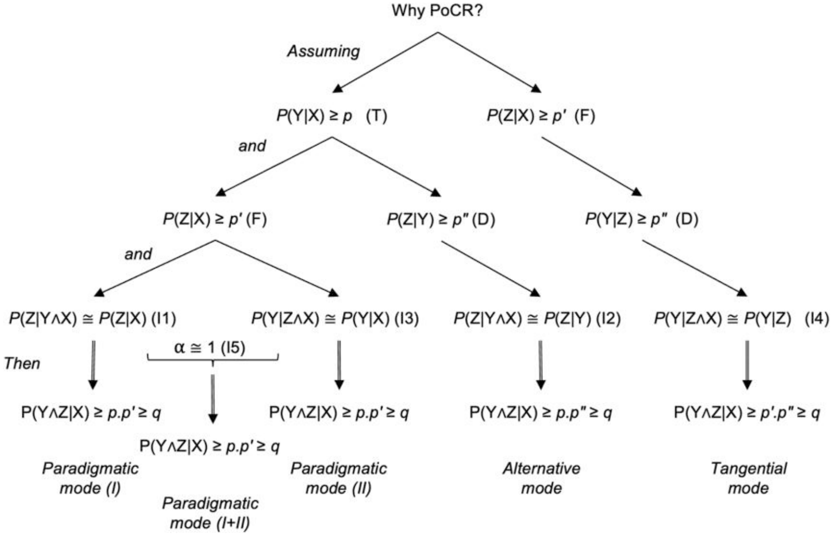

Fig. 4. *Decision tree for PoCR modes of reasoning.* Choice of sets of plausible assumptions lead to specific modes of reasoning for motivating PoCR.

objects exhibiting the central property X which is the focus of the research. Confidence in (T) is motivated by background theoretical knowledge about these X-objects possibly exhibiting Y (hence the controlled experiment envisioned in the PoC demonstration). Confidence in (F) stems from background knowledge about Z, typically instances of Z in the context of other (non-X) objects. In the nanochannel case, confidence in (T) arises from theoretical work about nanochannel structures and their capacity to create voltage gradients, while confidence in (F) stems from technological and engineering knowledge about scaling in general and its applicability to X-objects in particular. All paradigmatic modes build on the confidence in both assumptions. On the other hand, the alternative and tangential modes rely on (D), the confidence in which varies. It can be high due to numerous joint observations of Y and Z, notably when Y and Z are common; this is the case for large electricity-producing systems such as generators, dams, and nuclear reactors. Yet when Y or Z, or both, have rarely been observed, confidence in (D) may be low.

Among the indifference assumptions used to transform $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ into manageable expressions, (I1), (I3) and (I5) involve inductive inferences based on existing knowledge about the relationships between Y and Z across various known objects—notably in terms of indifference or independence of one property with respect to the other—and generalize this knowledge to the novel class of X-objects. Confidence in these assumptions is passed on as confidence in the paradigmatic modes of reasoning (left-hand side of Figure 4). On the other hand, (I2) and (I4) are more tenuously justified since they rely on inferences about X-objects, for which knowledge is scarce in the PoCR context. These two hypotheses should therefore usually be less favoured. Nonetheless, they may still contribute to justifying PoCR, albeit along the alternative and tangential reasoning modes respectively (right-hand side of Figure 4).

By corroborating (T), a successful PoC demonstration also plays a crucial part in prioritizing reasoning modes, favouring the paradigmatic and alternative modes which rely on (T), unlike the tangential mode. Indeed, a successful PoC demonstration will play the crucial role of increasing confidence in (T) and thereby in the fact that $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$.[7]

Consider for instance mode (I), which leads to expressing $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ as $P(\mathrm{Z} \mid \mathrm{X}).P(\mathrm{Y} \mid \mathrm{X})$ (equation 3). Prior to a PoC demonstration, (T) states that $P(\mathrm{Y} \mid \mathrm{X}) \geq p$. Confidence in (T) is itself expressed by a probability distribution. This shows in the prior probability $P(\mathrm{T})$ attributed to (T) before carrying out a PoC experiment, and in its revised posterior probability $P(\mathrm{T} \mid \mathrm{PoC})$ after successful PoC demonstration. In a Bayesian confirmation framework, these two probabilities are related as follows:

$$P(\mathrm{T}|\mathrm{PoC}) = P(\mathrm{PoC}|\mathrm{T}) \,.\, P(\mathrm{T})/P(\mathrm{PoC}) \tag{8}$$

Since the theory (T) is what makes the PoC likely, $P(\mathrm{PoC} \mid \mathrm{T}) \geq P(\mathrm{PoC})$. With (8), it follows that $P(\mathrm{T} \mid \mathrm{PoC}) \geq P(\mathrm{T})$. This increased confidence in (T) can in turn be translated into a more stringent theory assumption (T*) stating that $P(\mathrm{Y} \mid \mathrm{X}) \geq p^* \geq p$. Since the PoC does not concern property Z, one can assume that $P(\mathrm{Z} \mid \mathrm{X})$ remains unchanged. A new threshold $q^* = P(\mathrm{Z} \mid \mathrm{X}).p^*$ can be chosen such that, after a successful PoC demonstration, (3) leads to reassessing $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q^* \geq q$. This is to say that the likelihood of the overall target envisioned in the context of PoCR increases following a successful PoC demonstration. A similar reasoning takes place with the other paradigmatic and alternative modes, though not with the tangential mode, which does not rely on (T).

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[7] Failure of PoC demonstration would obviously be taken as a setback, bringing negative evidence against (T) or even refuting it, thereby lowering $P(\mathrm{Y} \mid \mathrm{X})$ and $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X})$ to the vicinity of 0.

These considerations on the plausibility of the different assumptions together with the use of a successful PoC demonstration lead to favouring the paradigmatic modes of reasoning, since they mobilize the most plausible assumptions (T), (F) jointly with either (I1), (I3) or (I5), thereby also making use of a successful PoC demonstration. Though also relying on (T) and making use of PoC success, the alternative mode of reasoning relies on (D), which is about the general pairing of properties Y and Z, and does not concern the X-objects under study. Coupled with assumption (I2)—which relies on the narrow inferential basis constituted by X-objects—this alternative mode of reasoning is likely to be less convincing than either of the paradigmatic ones. As for the tangential mode, it uses (F) and (D) jointly with the tenuous assumption (I4), and does not leave any room for a successful PoC demonstration to influence our confidence in the existence of the target. Though this mode of reasoning is conceivable, it seems more akin to *a priori* reasoning, and stretches the limits of what might be considered proper PoC reasoning.

Ultimately, the choice of certain assumptions over others dictates the adoption of a specific mode of PoC reasoning. The plausibility of these assumptions and the role given to a successful PoC demonstration contribute to making some modes preferable to others. Paradigmatic reasoning modes should typically be favoured over the alternative mode, which in turn should be preferred to the tangential mode. The final selection among the three paradigmatic modes depends on contextual factors. If there is more evidence suggesting indifference of Z to Y (or Y to Z) for the X-objects under study, mode (I) will be favoured (or mode (II), respectively). If background knowledge is evenly balanced, the null hypothesis will likely be selected, thus favouring mode (I+II).

This analysis also suggests actionable strategies to enhance motivation for PoCR. Strategies that boost confidence in (F) and either (I1), (I3) or (I5) can be employed for the paradigmatic modes, while actions increasing confidence in (D) and (I2) may be beneficial for the alternative mode. These strategies provide possible argumentative approaches for different PoCR contexts.

6. Further considerations

While the triadic model makes it possible to understand the inner workings of PoC reasoning that may motivate PoCR in the first place, it also accommodates novelty and projectability, two crucial aspects of PoCR

(Kendig, 2016; Elliott, 2021). Novelty in PoCR emanates from the fact that no PoC demonstration has ever been successfully attempted.[8] Consequently, the theory that motivates (T) has the status of a hypothesis, and whether objects with property X can exhibit Y is entirely unknown (for example, whether nanochannels may indeed produce high-density electricity). A successful PoC demonstration breaks new ground by establishing for the first time the possibility for objects with property X to also exhibit Y, at least with a reasonable probability: $P(\mathrm{Y} \mid \mathrm{X}) \geq p$ (for example, some nanochannels are indeed capable of producing high-density electricity). In less novel scenarios, research would be focused on extending the knowledge that supports (T), essentially increasing the value of p or specifying more narrowly the objects and properties that feature in (T) (for example, showing that new types of nanochannels can indeed produce high-density electricity, or even higher levels of energy). The novelty that characterizes PoCR also shows in the probabilistic framing of the proposed model, and the minimal quest for a non-empty and reasonably populated target (that is, $P(\mathrm{Y} \wedge \mathrm{Z} \mid \mathrm{X}) \geq q$), which has never been exemplified.

Projectability in the present context consists in asserting that what holds for the PoC demonstration—objects X exhibiting Y—should also hold in a different context, that is, jointly with property Z (for example, nanochannels that produce electricity are projected to continue doing so even when assembled into large membrane systems). In the triadic model we propose, projectability is ingrained in the interplay of assumptions concerning the three properties X, Y, Z, and the mode of PoC reasoning used.[9] Indeed, with the paradigmatic modes (I) and (II), a successful PoC demonstration—which shows the existence of X-objects exhibiting Y, thereby corroborating (T)—is used to bolster our confidence in the existence of X-objects also exhibiting Z in addition to Y, hence projectability. This is notably enabled by the two indifference assumptions (I1) and (I3), which already incorporate facets of projectability (justified from generalizations about objects with property Z or Y respectively, for which a large inference basis exists). The alternative mode of PoC reasoning also strives to provide good reasons for the target and for projectability by mobilizing a successful PoC

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[8] For Elliott (2021), novelty concerns the prototype, that is, the realization of X-objects, which entails novelty of the PoC demonstration. Here we locate novelty in the PoC demonstration, which may involve existing X-objects or new ones.

[9] In this respect, the triadic model explicates what Kendig (2016) simply takes as a promise and what Elliott (2021) formulates as a heuristic: the use of a successful PoC demonstration to argue for projectability.

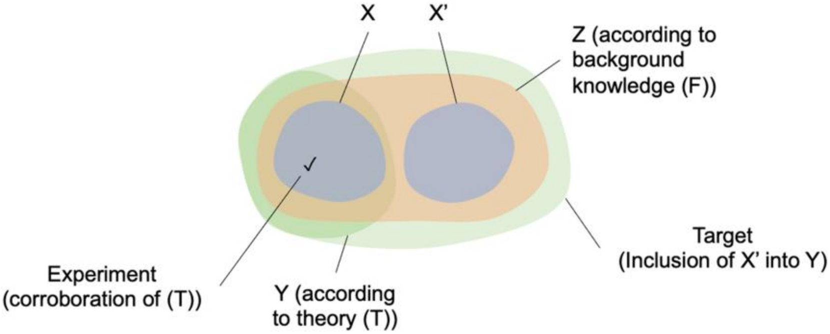

Fig. 5. *Analogical reasoning*. Research concerns source objects with property X (e.g. being a mouse) and target objects with property X′ (e.g. being a human). Background knowledge (F) gives good reasons to think that such objects also share property Z (e.g. possessing a specific metabolism). (T) gives good reasons to think that X-objects also have Y (e.g. being poisoned by a specific substance) and experiments are conducted to corroborate (T). Upon successful corroboration (e.g. mice can be poisoned by the substance), Y is extended to X′-objects (e.g. humans can be poisoned by the substance).

demonstration, but it does so by relying on the less straightforward indifference assumption (I2) (justified from a generalization about the little that is known, given a typical PoC context, about X-objects). As for the tangential mode, it does not make use of a successful PoC demonstration: assuming (F), (D) and (I4), it is as if projectability were inherently granted. Consequently, projectability garners support from a successful PoC demonstration only in the paradigmatic and alternative PoC reasoning modes.

An interesting contrasting case of ampliative reasoning is analogy, which leverages specific similarities between two objects to infer further similarities (see, for example, Bartha 2010). For example, similarities between animal models and humans are often invoked to justify the plausibility that specific properties observed on animal models will extend to humans (LaFollette and Shanks 1993).[10] Formally (Fig. 5), two types of objects, source X and target X′, possessing distinct properties (for example, being a mouse and being a human) are described as possessing a common set of properties Z (for example, exhibiting the same type of metabolism) according to accepted background knowledge (F). Additionally, other theoretical background knowledge (T) suggests that

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[10] For a recent debate on the use of analogical reasoning in physics, see Dardashti et al. (2019) and Crowther et al. (2021).

X-objects also possess property Y (for example, being poisoned by a specific substance). An experiment or an observation is typically called upon to corroborate that X-objects indeed possess property Y. Given the Z-similarities between X-objects and X′ objects, Y is then extended to X′-objects (for example, giving good reasons to think that humans will be poisoned by the substance).

More formally, analogical reasoning follows the argument pattern:

$P(\mathrm{Z}|\mathrm{X} \vee \mathrm{X}') \cong 1$ (according to background knowledge (F))
$P(\mathrm{Y}|\mathrm{X}) \cong 1$ (following corroboration of (T) by experiment)
$\therefore P(\mathrm{Y}|\mathrm{X}') \cong 1$ (by ampliative inference)

Like PoC, analogy involves projectability regarding a property of interest given background knowledge about a larger set of other properties. Analogy also relies on the corroboration of theoretical elements by an experiment. However, argumentative patterns differ significantly: whereas PoC reasoning assesses the probability that the intersection between three properties of interest will be non-empty (Fig. 1), analogical reasoning focuses on the inclusion of the target-object property within the property of interest (Fig. 5). Consequently, the supporting argumentative patterns are different, and so are the motivations for conducting either research.

7. Conclusion

The triadic model provides an understanding of the different sorts of reasoning patterns used to motivate and justify PoCR. The model relies on assumptions about the pairwise likelihoods that three properties of interest will obtain and about the relative behaviour of two properties given a third one. As elucidated, depending on which sets of assumptions are favoured, several modes of reasoning can be mobilized, some paradigmatic of PoCR and more compelling, others alternative or even tangential. In addition to their specific sets of assumptions, the peculiarity of these modes of reasoning lies in the pivotal role assigned to a successful PoC demonstration, particularly in enhancing confidence in projectability. Unpacking the logic of PoCR in this manner provides a nuanced understanding of the intricate modes of reasoning at work in this type of research, highlighting key assumptions made along the way and charting possible shifts in research strategies depending on changes in favoured assumptions, possibly in turn warranting further investigation. This nuanced understanding should aid practitioners in comprehending the underlying logic of PoCR and facilitate more informed and insightful approaches. It should also offer insights into the justificatory principles guiding a broader spectrum of speculative scientific endeavours on one form or another of ampliative reasoning.[11]

Conflict of Interest statement

The authors declare none.

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