Aion Journal of Philosophy and Science 2, 2025

Generation of hypotheses and problematic portions of phenomena

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Abstract
In this paper, we present our inferential and dynamic conception of surrogate reasoning in scientific modeling. To this end, we redefine the notion of hypothesis generation and delve deeper into distinctions that we consider fundamental, such as that of the problematic portion of phenomena. We conclude by pointing to a precedent for our approach in Constructive Type Theory.

Keywords: *hypothesis, models, scientific representation, surrogate reasoning.*

Resumo
O objetivo deste artigo é apresentar a nossa concepção inferencial e dinâmica do raciocínio substituto na modelagem científica. Para isso, redefinimos a noção de geração de hipóteses e aprofundamos distinções que consideramos fundamentais, como a da parte problemática dos fenómenos. Concluímos apontando um precedente para a nossa abordagem na Teoria dos Tipos Construtiva.

Palavras-chave: *hipótese, modelos, representação científica, raciocínio substituto*

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Some preliminary concepts: model, portion of phenomena, objective system.

First of all, some terminological clarifications. We will refer to a model, in a very general sense, as a device (whether constructed or not, concrete or abstract) intended to explain, elucidate, clarify, understand, and/or predict (among other objectives) a phenomenal portion. We do not give details about the nature of models, as we believe that this is not relevant to our objective. However, we do point out, and this is very important, that we will only deal with those that are intended to perform substitute reasoning. In other words, we assume that they exist in the sense indicated above and that, of all their functions or roles in practice, we will focus on the inferential or logical aspect. We leave aside models that are not intended to fulfill this function.[1]

When we refer to the portion of phenomena [PF], we refer to the quantitative or qualitative data[2] that we have collected and from which we develop or choose a model. We understand that the data comes from a phenomenal source that emits it. However, on the one hand, we do not consider it equivalent to the portion of phenomena. The latter is only a cutout of data from the former. On the other hand, when working with data, we are not postulating the existence of the source and, therefore, we separate the modeling process from any ontological assumption regarding it. That is, we model to solve questions related to it, but we do not presuppose its existence nor do we model to prove that it exists. Often, we only have data (and sometimes very little and confusing data), since the phenomenon itself is not accessible. This is the case, for example, with macro or micro portions of the Universe, of which we can usually only collect a few fragmentary data using instruments. We also point out that the modeled 'portion of phenomena' is usually referred to in the general literature on the subject as the 'target system'[3]. However, as we have already argued in Redmond & López-Orellana (2022, 2023a, 2023b), it is important to be able to distinguish between the two, and we have therefore placed special emphasis on keeping them separate in our presentation.

Portion of phenomena and problematic portion of phenomena

Finally, we point out that from the broad spectrum of portions of phenomena that can be considered (including some that do not yet exist, such as those projected by the architect), our research focuses on a group that we classify as problematic

[1] In Redmond & RLO (2024) we give details of cases of models that are not intended for surrogate reasoning. See also in Redmond (2020; 2021a,b; 2022), Redmond & López Orellana 2023b; 2024a,b,c)

[2] This is all that matters, in our view, for consideration in the branch of modeling practice we are analyzing. We do not believe it is necessary to define a realistic, unrealistic, or anti-realistic approach in this matter.

[3] We maintain this designation in our research, although we are not postulating that it consists of or possesses the conformation of any type of system. It would be more appropriate to simply say "objective" of the model, but we do not want to stray too far from the language used by our colleagues in the development of these topics.

[PPF]. Below, we will give certain conditions that a portion of phenomena must meet in order to be a problematic portion of phenomena, but we do not intend to be exhaustive and, therefore, much less to establish a general criterion for defining what a problem is in science. We therefore have that a portion of phenomena is problematic [PPF] when:

i. we know that there is a source of phenomenal data, but we do not really know what it is like.
ii. we do not know whether there is a source of phenomenal data or not.
iii. we know that there was something, but due to the time gap, it is impossible to corroborate it directly.

Why would these portions of phenomena be a problem? In the first case (i), there are two reasons. The first is that we cannot identify the source due to a lack of information about it. This lack of knowledge about its nature (we do not even know approximately what it is) prevents us from directly developing or choosing a basic configuration for our model, greatly complicating the modeling process. And therefore, for the generation of the model (we mean: constructed or chosen), a cognitive process is triggered, closer to invention or artistic production (heuristics). In other words, more than ever, the modeling process must be carried out beyond all ontological constraints. If we wait to know what we have in front of us in order to model it, science would be lost. Normally, this limitation in the data for modeling comes from the macro or micro aspects of the portion of phenomena, or from the observational limitations inherent to human beings. For example, the different models proposed for the minimum portion of phenomena (Dalton, Rutherford, etc.), which contrast with the scale model of a dam that an earthquake researcher makes to evaluate its resistance through simulations. The former corresponds to a free play of the imagination (because it is a PPF), while the latter must conform to the original measurements of the dam and translate them into a scale model.

It should be added that when we say 'we don't know what it is', we are not pointing to ontological questions. However, despite having no ontological commitments, in order to generate a model we need a basic configuration in order to organize the information. This basic configuration for PPFs is certainly provisional in nature. Cases of PPFs would be, for example, the trichronic DNA model (Pauling and Corey, 1953) and the subsequent double helix model by Watson and Crick. The second reason is that it is not necessary, for some reason, to propose complementary data (from a complementary source): the data can be adjusted to the model.

The second case (ii) would refer to those models that postulate complementary data from a complementary source and that it is appropriate to postulate for the resolution of the problem. In other words, the data collected from the source does not include data considered extra for the modeling. The model not only gathers the data available from the source, but also gathers data proposed in a complementary manner in order to solve the problem. For example, in the case of disturbances in the orbit of a planet (e.g., Mercury), postulating that there is a source of gravitational force (we do not have this data) to explain the disturbance data (data that we do have). This would also be the case with Semmelweiss, who postulated cadaveric matter.

In the last case (iii), these are portions of phenomena that are not affected by the macro or micro but are prehistoric. If we dig up a dinosaur skeleton, it may be easier to model what it looked like when it was alive. But in most cases, only vestiges and traces are available, which can lead to different models. This lack of knowledge is often compensated for by using living beings as models. This is the case of the experimental model Polypterus (a lungfish found in different areas of Africa), which serves to explain the role of environmentally induced developmental plasticity in facilitating the origin of the terrestrial traits that led to the appearance of tetrapods in the Devonian period (Lopez-Orellana & Cortés 2019).

We believe that these cases are the most challenging for scientific and philosophical exploration, and it is the purpose of our work to explain how modeling works in them. We distance ourselves from other perspectives that develop more global approaches in which these PPF cases are anomalous cases that must be adjusted ad hoc for the global approach to remain valid.

Clearly, it is not what makes a PPF 'problematic' that the model must address in PPF. Although we clearly have the illusion that it has been resolved once the model works successfully. For example, we have the illusion that the model is a planetary system because it turns out that this basic configuration (a model inspired by our own solar system, not by direct data from the source) allows for predictions, clarifications, etc., all of which are successful. This basic configuration provided by Rutherford and Bohr was transitory from its very conception (we know this today more than ever). And the reason was—in our view—because they modeled a PPF, such as the so-called "minimum portion of phenomena" or, as some prefer, "of reality." This is otherwise presented as an empty expression, since even physics itself has shown that this last bastion (that of being the minimum portion) has not been reached.

Problematic portion of phenomena and representation

Considering these PPFs as a starting point for understanding the practice of modeling sets the direction for our research. First, it is clear that we are not attempting to develop a general theory of modeling, but only to explain how it works in these cases that we consider extreme, paying particular attention to the inferential processes involved (surrogate reasoning). It remains to be seen how far our proposal can be generalized.

Traditional approaches generally consider these cases of PPF as special cases that would require ad hoc adjustments to be resolved. The closest thing in the classical treatment of what we call PPF, in our view, is the distinction between the observable and the unobservable. There is a vast literature on this subject, as it has not gone unnoticed by any of the most recognized approaches, such as the *Received View* or the *Model-Theoretical View*. Our conception of what a PPF is quite close to what is commonly understood by non-observable. However, we believe that little or nothing has been said about how scientific practice, which begins with the generation of a model, is carried out when confronted with the non-observable. Except, of course, if we consider cases in which the theory itself consists of a family of models (*Model-Theoretical View*), and these distinctions are already predetermined. The latter is in line with the ideal of reconstruction that inspires some philosophical developments on scientific practice.

One of the most challenging notions in all these processes is, we believe, that of scientific representation. An inspection of the article by Frigg & Nguyen (2017) makes it clear that the item: 'representing the unobservable' does not exist. It even seems absurd to raise such an issue. Some will consider it more appropriate to play with the boundary between the observable and the non-observable until they can accommodate their approaches to representation. The latter is especially true when aided by measuring instruments. However, none of these approaches seem reasonable to us. We are convinced that measuring instruments do not provide concrete data on the basic configuration of an unobservable PF, but rather organize the information we have into certain pre-established configurations. In other words, we believe that no measuring instrument is neutral. All are constructed within the framework of a theory that predetermines what that instrument delivers as data (*theory-ladeness*).

We therefore conclude that, from these traditional perspectives, PPFs would be a non-observable portion of phenomena. We define them as such because data on their configuration is absent or because we are proposing a model for which we have incorporated data on a source that is not only non-observable, but about which we do not even have concrete data. In a way, from our point of view, we are considering that a non-observable PF is one that does not provide information about its basic configuration. That is, according to the available information, it could be one or several, it could be this or that, or worse still, we have no theoretical framework to know what it would be.

All these considerations support our idea that the notion of representation must be questioned here. Even adjusting the distinction between the observable and the non-observable (cf. authors who do so), we can hardly establish a structural or similarity relationship between the model and PPF. Much less can it be the basis for logical processes such as surrogate reasoning. However, our point is that even in the case of a PPF, it can be modeled very successfully. And that success is largely determined by surrogate reasoning. For it is surrogate reasoning that allows us to establish a useful relationship between the model and PPF (anticipating, predicting, explaining), even if the PPF remains as such forever.

Representational versus logical thinking

We basically understand that surrogate reasoning starts in the model. But since the model is a 'model of' a phenomenal portion (these are the cases we are considering in this article), when we reason in the model we are at the same time, in a surrogate way, reasoning in that portion of phenomena. The expression 'at the same time' means that this is our intention as long as we are engaged in a modeling practice. The term 'surrogate' refers to this strange way of reasoning about one thing as if it were another[4]. However, some clarifications are necessary in this regard. That the model is a 'model of something' is understood here as one of the modes of representation, specifically scientific representation. But whatever notion of representation we choose (there is more than one), our point is that surrogate reasoning cannot find its ultimate foundation in it. That is, to claim that the conclusions obtained in M are also conclusions in the portion of phenomena cannot be justified by the fact that M represents PF. Why? Because surrogate reasoning is a mode of reasoning and must find its reasons and bases in logic itself, and the notion of representation is not a logical notion. After all, what is Representational Thinking? The mere formulation seems to indicate that I am entitled to carry conclusions from one side to the other in the name of representation. It may be an idea that finds some support in so-called analogical reasoning for cases such as the architect who models a house or the engineer who models an airplane turbine. And as long as, according to the theory, it is a matter of properties of one that I attribute to the other. But, in our view, this is a difficult idea to sustain, for example, in cases of scientific research where, as we pointed out above, enormously large (astronomy) or enormously small (atomic level) portions of phenomena are modeled. Only Suárez's (2004) proposal seems to assume these limits and proposes a radical version of representation in terms of surrogative reasoning (see Appendix 1). But even so, we believe that it has not managed to separate itself sufficiently from the notion of representation: the idea remains that we go from one side to the other transporting statements. Ultimately, it is not clear from this perspective what surrogate reasoning is, what its definition is, only that we perform them and that they can be successful.

Surrogate reasoning and hypothesis generation

The formula 'surrogate reasoning' was given by Swoyer in his 1991 article (p. 449). There we can read that Swoyer understands it as a type of reasoning based on representation (Structural representation for Swoyer). But it is worth mentioning that he does not mention that it consists of 'generating hypotheses'. In fact, Swoyer reserves 'hypotheses' for another meaning. Indeed, in his article he points out that it is certain hypotheses that make surrogate reasoning possible and not that the latter consists of them:

[4] "An activity as mysterious and unfathomable as soothsaying or divination" (Contessa 2007, 61).

> Modal facts have a structure. For example, if it is a fact that a is necessarily P, then a is actually P, and if a is actually *P*, then *a* is possibly *P*. My **hypothesis** is that possible-worlds semantics - or, more precisely, the Kripke model structures it employs - **provides** a structural representation of such facts, and that this is what **justifies** its use in surrogative reasoning about them. (our emphasis, p. 495)

Here, hypothesis seems to mean the basic assumptions I make (Kripke model structures) that make surrogate reasoning possible.

A few years later, we find the formulation of 'hypothesis generation' in Contessa (2007, 51, emphasis added):

> Consider again the entirely unfaithful model example. At some point we might have believed that some of the inferences from the model were sound, however this does not need to be the case. Sometimes a model of a system can be put forward as purely hypothetical and conjectural, without anyone believing that any of the conclusions about the system drawn from the model are going to turn out to be true. The model can be used as a **generator of hypotheses about the system**, hypotheses whose truth or falsity needs to be empirically investigated.

Here Contessa seems to mean that the inferences obtained in the model (or its conclusions) are hypothetical in nature in the target. And in this sense we find it summarized in Frigg (SPE, emphasis added):

> A first important condition of adequacy on any reply to this problem is that scientific representations allow us to form hypotheses about their target systems. An X-ray picture provides information about the bones of the patient, and models allow investigators to discover features of the things models stands for. Every acceptable theory of scientific representation has to account for how reasoning conducted on representations can yield claims about their target systems. Swoyer (1991: 449) refers to this kind of representation-based thinking as "surrogative reasoning" and so we call this the Surrogative Reasoning Condition.[2] This condition distinguishes models from lexicographical and indexical representations, which do not allow for surrogative reasoning.

These 'claims' (as Frigg puts it) are not the same as those pointed out by Swoyer, but they seem to match the meaning intended by Contessa and summarized very well by Lalande (1997, 429): ("C. a doubtful but plausible conjecture, whereby the imagination anticipates knowledge, and which is destined to be verified at a later date

[...]"[5]). However, we believe that there is a careless use of the notion of hypothesis here. Clearly, not all hypothesis generation, in the sense of 'claims' indicated above, corresponds to an inferential process. In other words, to paraphrase Contessa, if "scientific representations allow us to form hypotheses about their target systems," not all of these hypotheses come from "how reasoning conducted on representations can yield claims about their target systems." A detailed study of the ways in which we can produce hypotheses from a model does not exist today, but it would be difficult to argue that, in the sense c indicated above, their only source is reasoning. Perhaps this careless use of hypotheses is due to the difficulty of determining or reconstructing these creative processes of generating new ideas such as hypotheses.

We retain for our work, then, that these hypotheses—as these authors think of them—initially conform to 'meaning c', but enriched with the following: they are the consequence or result of an inferential process that takes place in the model, and are then carried (Swoyer speaks of them making a journey [1991, 452, 474, 487]) to the target system. And that the path along which this journey travels is the path of representation. We will call the latter the static approach to inferential hypothesis generation in the model. And how would these hypotheses be generated inferentially in the model? Well, there does not seem to be any restriction. Based on the data in the model, one could proceed by deduction, induction, or even abduction. But these are always performed in the model.

Dynamic approach to inferential hypothesis generation in the model

Our approach distances itself from the static perspective, but we maintain the idea that surrogate reasoning is generating a hypothesis from the model and about the portion of phenomena modeled.[6] In this sense, we maintain that instead of saying that the conclusions in the model make a journey to PPF, we say that the proofs performed in the model are at the same time (in a surrogate manner and by agreement) proofs performed in PPF.[7] We will call this the dynamic approach to inferential hypothesis generation in the model. Let's look at this in detail.

Our starting point is the re-signification or reformulation of the notion of 'hypothesis generation'. In our perspective, 'generating a hypothesis' is generating a logical interaction between two pieces of evidence. In this sense, according to our point of view, our approach involves a pragmatic shift in the understanding of surrogate reasoning (see below). Indeed, the notion of use and epistemic agents with their purposes aligns with our proposal and can be summarized as follows:

[5] "C. Conjecteure douteuse, mais vraisemblable, par laquelle l'imagination anticipe sur la connaissance, et qui est destinée à **être** ultérieurement verifiée […]"

[6] This idea was inspired by the This idea was inspired by the hypothetical demonstrations used by ancient geometers and mentioned by Plato in Meno 86e and Aristotle in Prior Analytics 50a.

[7] In the general literature, the modeled portion of the phenomenon is called the target system. However, we distinguish between the two according to our redefinition of the objective system in order to offer a possible solution to the Targetless problem (Cf. Lopez & Redmond 2024).

> There is an agent *A* who uses the model to generate a hypothesis by proposing an interaction between the evidence for a proposition *p* in *M* and the evidence for the same *p* in PPF for the purpose *P*.

As we pointed out above, in such an interaction, one proof substitutes for the other on the basis of an agreement, which we schematize as $A \rightarrow_{[Hip]} B$ which reads: the proof of *A* is also, by substitution, the proof of *B*.

The latter is the hypothesis generated on the basis of an agreement between interlocutors who, aligned with their purposes, established that logical relationship between M and PPF. The constructed interaction establishes that what is proven in M remains proven in PPF in the sense that the justification for maintaining it in PPF is that it was proven in M. In this sense, we argued that the dialogical pragmatism approach is an ideal framework for formalizing this process (see articles).

To give an example, just as Gentzen considered that the relationship between $p \wedge q$ and *p* is a logical relationship (in fact, it is a rule) which he called conjunction elimination (simplification), the relationship between what is proven in *M* and what I consider proven (with sustainability) in PPF is a logical relationship (because the relationships between proofs, we argue, are a matter of logic). And that is why we believe it is so inappropriate to argue that the notion of representation justifies the latter, just as it is inappropriate to argue that the passage from $p \wedge q$ to *p* is justified by some kind of structural correspondence or similarity or that, since it is logically successful to pass from $p \wedge q$ to *p*, then *p∧q represents p*.

In the static approach, what is normally said is that what is proven in M is hypothetical in PPF. Of all the statements that could be carried from M to PPF, and which are all hypothetical until proven (Lalande's sense c), those that were inferred in M correspond to the process called surrogate reasoning.

For our dynamic approach, then, surrogate reasoning is generated dynamically from the agreement between epistemic agents who construct an interaction between proofs. This logical interaction can be schematized as follows:

$$\Vdash_M C_i \rightarrow_{[Hip]} [\Vdash_M C_i]_{PPF} \quad (1)$$

If I proof C_i in M, then C_i will have sustainability in PPF

In this diagram, the expression $\Vdash M\ C_i$ means the set of conclusions $\{C_1, C_2, \ldots C_n\}$ obtained in the model. Meanwhile, the expression $[\Vdash M\ C_i]_{PPF}$ means that those conclusions obtained in M have sustainability in PPF. The latter is indicated by the expression "$\rightarrow_{[Hip]}$" which conveys our idea that a hypothesis has been generated.

In our perspective, there is a pragmatic shift in the understanding of surrogate reasoning. Indeed, the notion of use and epistemic agents with their purposes aligns with our proposal and can be summarized as follows:

> There is an agent A who uses the model to generate a Hypothesis proposing an interaction between the proof of a proposition p in M and the proof of the same p in PPF for purpose P.

As we pointed out above, this pragmatic turn in the understanding of surrogate reasoning was captured in our previous articles from the perspective of dialogic logic (Redmond & Lopez-Orellana 2023b, 2024b, 2024c). Indeed, dialogic logic is a pragmatic perspective on logic that provides us with the necessary elements to represent the logical interactions that, from our point of view, are at stake in the modeling process.

This way of understanding hypothesis generation, we believe, is closer to the treatment of dynamic systems. Indeed, in the static perspective, it is not taken into account that, when generating a hypothesis, PPF could have changed, for example, if one thinks of dynamic systems such as living beings. That is why we believe that, if hypothesis generation is thought of as an interactive construction, it can be more aligned with the mutations (regular or otherwise) that would affect PPF.

In this sense, we have already argued elsewhere that surrogate reasoning has characteristics in common with defeasible reasoning:

> Reasoning is defeasible when the corresponding argument is rationally compelling but not deductively valid. The truth of the premises of a good defeasible argument provides support for the conclusion, even though it is possible for the premises to be true and the conclusion false. In other words, the relationship of support between premises and conclusion is a tentative one, potentially defeated by additional information. (Koon 2021)

Surrogate reasoning is defeasible, according to Koon, because the proof of p in M does not guarantee that the evaluation of p in PPF will be positive, either because the generated hypothesis is incorrect or because the current state of the modeled dynamic system could not be correctly predicted with the hypothesis. Aristotle was already aware of this and therefore classified this type of reasoning as dialectical rather than ostensible or scientific (according to Aristotle's understanding of science). According to the latter, it would be possible to consider the practice of modeling, from an inferential point of view, within the framework of Belief Revision (Redmond 2020).

We summarize as follows: Why is SuR a kind of logical thinking? Because it is an interactive relationship between two logical proofs, where one replaces the other by agreement.

In conclusion: Dynamic substitution and dependence between proofs

Our point, then, is that we must understand the notion of substitution from an inferential and dynamic point of view. To put it bluntly: there is no substitute other than the action of substituting, understood as the action of establishing a logical relationship: that what is concluded in M is sustainable in PPF. To reason surrogate is therefore to establish this logical correspondence between M and PPF.

A logical correspondence that can also be read, from our point of view, as a relationship of dependence. Substituting is, then, establishing a dependence between proofs: the proof of p in M becomes the proof of the sustainability of p in PPF.

A very important antecedent that would help consolidate a logical justification of surrogate reasoning can be found in the work of Per Martin-Löf (1984). Indeed, in the Constructive Type Theory (CTT) approach created by Martin-Löf, the explanation of the meaning of the conditional A → B (Martin-Löf, 1984, p. 7) consists of a method that leads any proof of A to a proof of B. Thus, for Martin-Löf, hypothetical judgments are "judgments made under assumptions" (p. 9). If we assume that A and B are propositions (they could be sets in Martin-Löf's perspective), the generalized form of these judgments is

b(x):A(x) (x:B)

which is interpreted as follows: b(x) is a proof object (dependent) of A(x), provided that x is a proof object of proposition B. From our perspective, we would say that A substitutes B whenever there is a proof object b(x) of A, provided that x is a proof object of B.

In relation to Martin-Löf's work, Goran Sundholm interprets the conditional [(2) if A is true, then B is true] as follows:

> The conditional (2) is a hypothetical judgment in which hypothetical truth is ascribed to the proposition B. Its verification-object is a dependent proof object B:proof (B) [X:proof (A)], that is, b is a proof of B under the assumption (hypothesis, supposition) that x is a proof of A. (Sundholm, 2019, p. 555)

From our perspective, this dependency corresponds to the substitutive nature of the reasoning established between M and PPF.

Acknowledgments

This article was made possible thanks to the support of ANID, Chile, **Fondecyt Regular Project 2024-26, No. 1241930**.

Appendix 1

Suárez's strategy is therefore to review what these general conditions might be. He believes that the best way to define the scientific concept of representation is through two necessary conditions: its essential directionality (or representational force of its source) and its capacity to allow surrogate reasoning and inferences. Based on this, the notion of representation involved in the scientific activity of modeling should be considered minimalist and deflationary, analogous to minimalist and deflationary definitions of truth. For Suárez (2004, pp. 770-771), this means 1) abandoning the search for universal necessary and sufficient conditions that are met in each and every concrete instance of scientific representation. Representation is not the kind of notion that requires or admits such conditions. At best, we can only attempt to describe its most general characteristics. Furthermore, 2) it means ceasing to identify and associate characteristics with representation that are deeper than those already found on the surface of the practice itself. Representation then has only the following irreducible features:

> i. the representational force of its source (or model), which is expressed in the following scheme: 'A represents B only if the representational force of A points to B; and
> ii. the inferential capacity, which allows for surrogate reasoning.

The item i. simply points out that a model M is used by an agent A (the scientist) in their practice of scientifically representing a phenomenon f. In this way, it is sufficient to analyze the use of M to understand its function and scope. It reduces representation to the use of M and the 'directionality' of M towards f. Now, ii. simply indicates that M allows A to extract specific hypotheses about f. These hypotheses do not have to be considered 'true', since models only provide us with an approximation of f. The inferences we make about f are plausible; there is no reason to claim that they are true.

Suárez warns that i. does not imply only a basic or ordinary form of representation, which is usually identified as denotation, but that—as *scientific representation*—it adds a characteristic form of *objectivity* to the phenomenological features of ordinary representation, which simply translates into its cognitive value. This is very important for cognition with models, and it is only in this sense that we speak of 'objectivity'.

> Scientific representations have cognitive value because they aim to provide us with specific information about their objectives. The information they provide is specific in the sense that it could not be equally conveyed by any other arbitrarily chosen sign [a model, or any other tool of representation]. (Suárez, 2004, p. 772)

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