Theory Construction and The Projectability of Meta-Inductive Arguments★

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Scientists and philosophers of science often draw methodological lessons from successful theories to justify methods of theory construction and to guide research programs.This paper proposes an epistemic framework for this practice, articulated in terms of the notion of meta-induction. By analogy to Goodman's 'New Riddle of Induction', it introduces the concept of projectability of meta-inductive arguments, and demonstrates its significance in any account of meta-inductive reasoning. Likewise to scientific induction, meta-induction is shown to be constrained by naturalist epistemology in determining which classifications of theoretical methods are 'projectable'. Projectability judgments in meta-inductive arguments help ensure that when taking lessons from past theorizing (either as a part of scientific discussions or in a philosophical reflections about science), they would be based on the way evidence was exploited in theory construction or on theoretically plausible hypothesis about the natural world, rather than on human-made concepts. This framework emphasizes the primacy of empirically guided patterns of conjecture over purely formal considerations, enabling epistemic evaluation of research projects, even when theorizing is primarily grounded on abstract theoretical methods and at stages when direct evidence is unavailable. The paper discusses possible implications on philosophical debates concerning theory assessment in fundamental physics, particularly regarding meta-empirical justification, as well as discussions on model transfer in the special sciences.

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1 Introduction

Scientific theory construction is a complex, layered practice. It is guided by available evidence and accumulated disciplinary knowledge, framed by conceptual frameworks, and inevitably shaped by historical and sociological contexts. From an epistemological point of view, the hardest cases are those in which direct evidence is thin: in such situations, theoretical and methodological resources often do more of the work that evidence would otherwise have done. Indeed, many recent discussions in philosophy of science turn to focus on such methodological and epistemological aspects of theoretical scientific practice, particularly on how to justify and assess theoretical methods[1], theories, and research programs. In evidence-scarce settings these methodological considerations become both more significant and more challenging. The issue pertains to different fields. Contemporary fundamental physics provides one salient example, where the development of new theories, their justification, and the debates on choosing between them proceed with exceptionally limited direct evidence (Dardashti, Dawid, & Thébault, 2019). Different examples can be found in cases of transfer of quantitative modeling techniques across scientific domains or disciplines, often without clear empirical grounding in the target domain (Herfeld, 2024).

In approaching the issue, many current approaches tend to methodological pluralism, viewing it as in line with actual scientific practice, regarding theory construction as a process in which imagination and creativity should not be restricted (e.g., following Feyerabend, 1975/1993), and pointing out the advantage of exploring different possibilities in parallel and dividing cognitive labor (see, e.g. Chang, 2012; Duerr & Fischer, 2025; Šešelja, Kosolosky, & Strasser, 2012; Shaw, 2022, and references therein). However, in the relevant contexts, the assessment of premature potential research directions often becomes crucial, carrying significant implications for both the philosophy of science and scientific practice, including resource allocation and research strategy. In this kind of situations, justification in the context of pursuit becomes a matter of degree rather than a sharp binary distinction. What would count as a good justification for a claim that certain suggested theories or research programs are more likely than others to yield viable predictions? The idea of pluralism by itself cannot answer such questions. To establish standards of assessments, pluralism needs somehow either be constrained or complemented.

The subtlety of the question, together with its pressing significance, urges for the exploitation of all available epistemic resources. These include, beyond norms of rational discourse (on which see Duerr & Fischer, 2025), the content of current established theories, and also methodological lessons from the past process of theory development. Indeed, criteria of justification and theory choice such as theoretical virtues, principles, and frameworks, are often defended based on the claim that they proved valuable in past theoretical advances. The issue at hand is therefore that of drawing lessons from past science. Here, however, despite the many efforts that target individual principles or theoretical methods, there remains a lack of clear criteria for how to justifiably

[1] Theoretical methods is use here as a broad term, referring to the employment of formal considerations, mathematical modeling techniques, theoretical principles, etc (see §3.2).

and effectively learn from historical instances of theorizing, and the epistemic grounding for such methodological claims remains unclear. The central aim of this paper is to address this gap by examining the epistemological foundations for extracting methodological lessons from the historical trajectories of successful theories.

This issue involves a range of more focused questions. Is it possible to draw justifiable and general methodological lessons from successful theorizing? Under what conditions can the empirical success of a theory provide justification for other theories that are constructed using similar methods or principles? When a successful method can be described in several ways, or as a manifestation of different competing principles, how should we justify a choice of one of them as a basis for future theories?

The working hypotheses of this paper is that the epistemological standards that should be used in tackling such questions at the 'meta' level should be continuous with those of science. This view will be presented (§2) as based on a naturalist approach to the epistemology of science. In any of the various forms of this view, evidence plays a crucial justificatory role. Clearly, situations where evidence is lacking and suggested theories are far from yielding testable predictions pose significant challenges to this form of naturalism. To address this challenge, the core concept to be used here is meta-induction. Meta-induction would be understood here in a broad sense, as an attempt to generalize and draw lessons from cases of past theorizing (and their empirical successes and failures), and apply these lessons to ongoing theorizing. A central aspect of meta-induction, which is the one that would mostly be addressed in this paper, is the attempt to motivate and justify the applications of theoretical methods that are similar to ones that appear to have led to historical successes. Appealing to physical principles, theoretical virtues, or mathematical frameworks in theory construction are all forms of meta-induction, as far as the appeal is based on the applicability of these principles, virtues and concepts to theories whose empirical success has been established.[2] (Appealing to relevant historical examples for the assessment of other factors, such as potential costs of pursuing a research program, may also fall under the category of meta-induction, but will not dealt with explicitly in the scope of the current paper.)

Notably, the term 'meta-induction' already has several meanings in the literature. Here, the prefix 'meta' comes to signify that the inductive-like inference concerns the level of scientific practice and methods (§3). This is distinct from other uses of the term 'meta-induction', most notably from Laudan's (1981) 'meta-philosophical claim' (the pessimistic meta-induction). A notion of meta-induction that is much closer to the one presented here is found in the 'meta-inductive argument' by Dawid (2013, 2016), in which the empirical success of a theory supports theories that share the theoretical strategy and meta-level hypotheses (more on that on §4.1). A different but related notion of meta-induction that will be mentioned below has been introduced by Schurz (2018, 2019), as a means of providing justification for the choice of prediction methods from among a range of competing ones (*inter alia* in order to provide a noncircular justification for induction).

[2]For recent discussion in the philosophy of physics see Crowther (2021); Crowther and Rickles (2014); Holman (2014); Smolin (2017)

The naturalist approach that will be applied here is described in §2. The notion of projectability is introduced in §3.1 based on Goodman's (1983) 'new riddle of induction' and naturalist responses to this challenge. An analogous understanding of meta-induction and the significance of projectability judgments therein are presented in §3.2-§3.3. The relation of a naturalist reading of a theoretical method and its projectability is demonstrated in §3.4 using the example of the application of differential equations to various domains.

§4 touches upon the potential applicability of the account to debated issues in the philosophy of science. The first is the general issue of theory construction in current fundamental physics, including the relation of the current account to Dawid's meta-inductive arguments. The second is a more concrete example in physics, that of invariance arguments. It is demonstrated that this case manifests a 'new riddle of meta-induction', namely a situation in which competing accounts of the way given theoretical arguments work in theories that are considered as established, lead to diverging conclusions on theorizing in the context of open questions, and hence to distinct research programs. The third example is the recent discussions on model transfer in the special sciences, namely the practice of importing modeling methods from a certain science or theoretical context to other sciences or theoretical contexts. Finally, §5 reflects on the relation of the contribution of the concept of the projectability of meta-induction to existing accounts, and places the discussion in the broader context of scientific rationality in current historical approaches to the philosophy of science.

2 A naturalist approach to the epistemology of science

The question at hand is that of justification of methods and arguments employed in theory construction and, in particular, aspects of such justification that are not based on direct evidence. Notably, in some cases theory construction precedes direct evidence and these aspects are the only ones at hand. The working hypothesis of this paper is that even when it comes to such cases, the epistemic standards that should guide justification should be consistent with scientific standards. The aim of this section is to spell out this working hypothesis in terms of a naturalist approach to the epistemology of science.

Often contrasted with epistemic foundationalism, anthropocentrism or constructivism, the term naturalism refers with a cluster of ideas characterized by the aim for continuity of philosophy and science, while giving science a higher status, in some sense, in the domain of overlap between the two disciplines. Certain forms of naturalism can be seen as the view that science should replace or underwrite wide areas of philosophy. Thus, naturalizing metaphysics is the view that metaphysical claims can only be based on scientific theories (e.g., Ladyman & Ross, 2007). Naturalized epistemology is the view that the content of epistemological statements are no more than part of the domain of study of psychology or of cognitive science (as most famously suggested in Quine, 1969a). A related, and possibly even broader view is 'subject naturalism', comprehensively presented and advocated by Price (2011), who defines it as 'the philosophical viewpoint that begins with the realization that we humans (our thought and talk included) are surely part of the natural world' (p. 5).[3] The current project is limited to philosophical statements that concern science in addition to scientific claims at the meta level. It therefore does not require scientific imperialism over philosophy in general (even though some versions of the aforementioned views may not be incompatible with the presented view). What we need is a naturalist approach to the epistemology of science, namely the view that broad scientific standards and criteria should be seen as pertaining not only to scientific inquiry *per se*, but also to justification of meta-level scientific and philosophical statements and beliefs *about* this scientific inquiry.

Clearly, even among naturalist philosophers of science, there is no agreement on what constitutes these standards and on the extent to which they change in the course of scientific development. Different views on these questions can lead to different judgments on theoretical methodology. However, the aim of this paper is not to engage in detail with these questions. Instead, the aim is to show that the express aim to understand theoretical methods in light of a coarse grained and relatively uncontroversial view of scientific standards already contributes to some ongoing pivotal debates on epistemic aspects of theoretical methodology. Therefore, the naturalist approach that would be employed here is one according to which scientific understanding of natural processes privileges certain kinds of epistemic elements over others: Empirical evidence is a preferred grounding for justification. *Aposteriori* justifications and explanations should generally be preferred, when available, over *a priori* ones. Appeal to specific contingencies is a more desirable explanans than general necessities. The naturalist hypothesis we shall adopt would imply that these priorities should also shape our understanding of scientific progress.

While these preferences are relatively non-controversial in the given context, there are different ways in which they can be justified. Boyd (1980, 1991) advocates a similar view of contingency-based justification based on an anti-foundationalist epistemology. However, the suggested naturalist approach is also compatible with reliabilism, even one that stems from *a priori* justification Goldman (1999), or with other ultimate internalist justification for higher level forms of scientific justification as in Schurz (2019) (and see also §4.4). Basically, for the aims of the current paper, the epistemic preferences outlined by the suggested approach need only to be taken as valid in the context of the assessment of scientific theories and theoretical methods. Thus, the naturalist approach to the philosophy of science can be accommodated within naturalist epistemic framework that are very different from one another when it comes to other cases of justification (and are not essentially in conflict with an appeal to *apriorism* at the level of more fundamental questions).

3 The projectability of meta-inductive arguments

3.1 Projectability judgments

Faced with the question of what makes certain meta-inductive inferences more justifiable than others, philosophical discussions on scientific induction present us with a

[3] See Menon (2024) for a detailed discussion.

useful analogy, clearly expressed in Goodman's 1983 new riddle of induction, whose significance here is twofold. First, it helps to clarify the basic structure of inductive arguments, demonstrating their reliance on 'projectability judgments'. Furthermore, we shall see that in the case of meta-inductive inference, an analogous problem is a major and living issue, that pertains to both philosophy of science and science itself.

In 'The New Riddle of Induction' Goodman notes that past observations can be characterized in terms of infinitely many different predicates, that can accordingly give rise to many contradicting inductive inferences. In a famous example he points out that a set of observations compatible with the hypothesis that all emeralds are green is equally compatible with the hypothesis that all emeralds are grue (where the predicate *grue* 'applies to all things examined before [a certain time in the future] t just in case they are green but to other things just in case they are blue', p. 74). Goodman's riddle thus involves two inferences, equally consistent with the data and of identical logical form. There are different ways to understand the issue at stake and different strategies to tackle it. Thus, some attempts to resolve or dissolve the problem apply constraints over some aspect (e.g. the time-dependence, or 'positionality') of the predicates (e.g., Carnap, 1947; Jackson, 1975). Sometimes the 'new' element in Goodman's riddle is in highlighting the possibility of the language-dependence of qualitative properties. The non-linguistic justificatory role of the notion of projectability, according to this view, is to be understood in the context of Hume's 'old' problem of induction (Schurz, 2019). [4]

Goodman's papers and the subsequent discussions mainly focus on two related issues. First, the standard logical framing of inductive inferences from given data is consistent with clearly 'bad' inferences, that are associated with 'pathological predicates' like grue, that stand in contrast with ordinary predicates like green (e.g. Kahane, 1971; Schurz, 2014), such that projecting them amounts to a 'counterinductive' projection of the ordinary ones (Salmon, 1967). The second issue is the need for criteria that make certain projections better than others, namely more 'law-like', more projectable, or more plausible. In the current paper, our concern is with the epistemic aspects of this second issue, which is what we shall refer to when using the term 'the new riddle'.[5] Thus, putting aside specific features of the 'grue' example (such as time dependence) and also the linguistic aspect of the problem, the riddle is regarded as demonstrating the broad significance of the notion of projectability in inductive reasoning. Making a choice from among the possible classifications is an essential part of any inductive argument, yet this choice is never enforced by the evidence.

Putnam offers such a reading in his forward to Goodman (1983), according to which Goodman's problem 'is the projection problem: what distinguishes the properties one can inductively project from a sample to a population from the properties that are more or less resistant to such projection?'. In this view there are many cases in which there is no clear-cut line between ordinary and pathological predicates or properties,

[4] See also the discussion in Hacking (1991) and Boyd (1991) on Locke and Mill.

[5] The distinction between the issues is not always explicit in the literature, with some resources making a distinction between 'the new riddle of induction' and 'Goodman's problem' in relating to them. The second, epistemic, issue is the one Goodman reflects on in Section IV of Goodman (1983), and is identified with the new riddle in, e.g., Godfrey-Smith (2003); Moreland (1976); Skyrms (1975).

projectability is generally a matter of degree. While ostensively definable predicates (based on direct observation) have a preferred status manifested in their projectability, non-observational predicates can also 'acquire projectability' using mechanisms that 'depend upon a relation between one hypothesis and another' (p. xii). Thus, 'we don't want to rule out grue completely', and it is an advantage of Goodman's approach, according to Putnam, that it allows for these kind of subtleties.

A central approach towards Goodman's riddle is based on a pragmatic revival of the old notion of 'natural kinds'. Quine (1969b) presents a perspective according to which projectable classifications arise gradually from more basic notions of similarity, that are expressed, refined and become entrenched in the process that gives rise to accepted and established theories. The grouping and characterization of useful classifications is described by Quine, following Goodman's conception of entrenchment, as a 'second-order induction'. Quine, however, stresses that this process is conducted with the aim to reflect a real and objective relation of similarity in the world. Every inductive inference therefore depends on a projectability judgment, according to which a certain theoretically-based classification imposed on the data is preferable over others that are equally compatible with it.

Boyd (1991) presents a more developed and detailed account of projectability judgments with a strong emphasis on the way it manifests naturalist epistemology. Here, the appeal to natural kinds serves the purpose of establishing projectability judgments on an *a posteriori* basis. This justification of projectability judgments is always based on *background theories*, i.e., on both the theoretical content and the observational content of accepted theories that provide the background knowledge for the inductive inference.[6] The belief that classifications underlying inductive inference reflect natural kinds, i.e., that they originate in contingencies found in nature, therefore allows scientific induction to be understood as rational by science's own standards.

As a side note, it is important to mention a notable debate concerning the fundamental justification of induction. Some approaches regard the justification of induction based on the success of inductive arguments as an acceptable form of circular reasoning (Putnam, 1974; Quine, 1969a) that typically aligns well with an externalist and anti-foundationalist epistemology. This approach, of course, is not the only form of naturalism, and this circularity (as well as the appeal to second-order induction in which the problem can re-emerge) is sometimes criticized by approaches in the naturalist neighborhood (e.g. Salmon, 1957; Schurz, 2008). Tackling this fundamental epistemological debate is beyond the scope of this paper, but it is easy to note that the claims presented here do not depend on subscribing to externalist anti-foundationalism all the way through. For the purpose of this paper it suffices to aim for a coherence between general scientific standards of justification and the particular standards that are applied in theoretical practice and in meta-level reflections on it. An approach such as Schurz's (2019) in which methods of inquiry are assessed and justified based on their success in generating predictions, while at the same time providing at the

[6]The ultimate aim of Boyd's account is to facilitate an abductive argument for realism with respect to the content of background theories. This issue is orthogonal to the current discussion.

deeper level an *a priori* justification for this form of assessment, is not at odds with the claim made below.

To conclude, the resulting picture of inductive reasoning is characterized by a constant competition between different classifications or notions of similarity. Projectability judgments allow inductive reasoning by applying *a posteriori* theory-dependent standards to form comparative assessment of the plausibility that different classifications and notions of similarity would lead to empirically successful statements. We now turn to the task of presenting an analogous account for meta-inductive arguments and the role of projectability judgment therein.

3.2 Meta-inductive arguments

We are now in a position to recast our original question in terms of the projectability of meta-inductive arguments. The aim is to account for the epistemic aspects of the way scientists use the experience accumulated in past cases of theory construction to construct new theories. The issue pertains to various considerations used in theory construction when they are motivated, articulated or justified in a way that is not directly based on the evidence available in the given scientific context. We shall broadly refer to such considerations as *theoretical methods*, using the term in a broad sense that includes practices such as the employment of mathematical modeling technics, formal frameworks, physical principles, or theoretical virtues. 'Meta-inductive arguments' motivate and justify certain theoretical methods in a given context based on past theories that used similar methods (possibly applied to different scientific domains or target systems), i.e. they involve the projection of classes of theoretical methods from established theories to suggested ones.

This task requires identifying notions of similarity between theoretical methods, that would give rise to projectable classifications of them, and thus to projectable meta-inductive arguments. This is clearly not an easy task. There are usually many ways to understand and reconstruct any theoretical method, and accordingly, theoretical methods can be classified in many different ways. The extrapolation of theoretical considerations to the generation of new theories can be done in numerous ways, and there is not always any clear notion of similarity. To approach the question we turn to examine whether the naturalist treatment of the projectability of inductive arguments can be extended to cases of meta-induction.

There are, *prima facie*, good reasons to doubt the possibility of such an extension. Theoretical methods can be based on an intricate and often inseparable combination of empirical, theoretical, mathematical, and hypothetical considerations. We would not expect such considerations to fall under 'natural kinds'. Furthermore, the question of projectability is often cast in terms of confirmation: under what conditions does a body of data support a particular inductive step? It would make less sense to ask under what condition does a body of data support the use of a certain theoretical method. The question of the projectability of meta-induction therefore departs in some ways from the discussion on induction. Yet, there are also similarities. Like in the case of induction, the question here concerns judgments of theoretical plausibility and the way they reflect on the rationality of the scientific process. Given the past success of a set of theoretical arguments that fall under a certain classification, when will it be rational to expect that other arguments falling under this classification would lead to empirically successful theory? Our aim here would be to show that the approach to induction outlined in the previous subsection is also relevant here.

This task requires a more detailed account of what meta-inductive arguments actually are. To accommodate them in a broader picture of the scientific process, we shall define meta-inductive inferences as an inductive-like inferences, for which the relevant target system includes not only the physical systems that are the subject of inquiry (e.g., emeralds, or elementary particles), but also the scientific community that studies those physical systems. In other words, the process we are concerned with is theory construction, and its components include both the relevant physical objects and the community studying them (including the community's knowledge and the theories being employed). It is assumed that the community is a scientific community in the sense that theories are primarily judged based on their empirical adequacy.

On this view, the agent making the meta-inductive inference describes the scientific process from a third person perspective (Figure 1). For the sake of clarity, let us distinguish between the physical system of interest, and the *meta-system* that includes the system and the scientific community.[7]

Let us now assume that in the course of the scientific process a theoretical argument has been employed, giving rise to a new theory. Later, the predictions of the theory are put to experimental test. After this process has been carried out several times (with some theories turning out to be empirically adequate, and others inadequate) a meta-induction is in place. In this description, standard induction and theoretical considerations are employed from within the meta-system (i.e., by the scientific community, in the context of the relevant background knowledge) while the meta-inductive inference is made from an external point of view. A meta-inductive inference is based on identifying a similarity among theoretical considerations that have led to empirically adequate theories, and will argue in favour of theories that were not yet put to experimental test, but were nevertheless constructed using similar theoretical considerations. The argument can go further, and articulate a way of applying similar considerations in theory construction, thus suggesting new theories.

3.3 Projectability judgments in meta-inductive arguments

According to the naturalist view of scientific induction, projectability judgments are *a posteriori* theory-dependent classifications of scientific terms, identified (in a cautious, revisable manner) with natural kinds. In the case of meta-induction, the relevant classifications are of theoretical arguments. The question at hand is which notions of similarity among theoretical arguments are projectable. While formulating agreed criteria for identifying such notions may not be an easy task, it is easier to observe that some notions of similarity are clearly non-projectable. For instance, the success of

[7]The physicalist would further argue that the meta-system is also a physical system. This stronger statement is not an essential part of the current analysis.

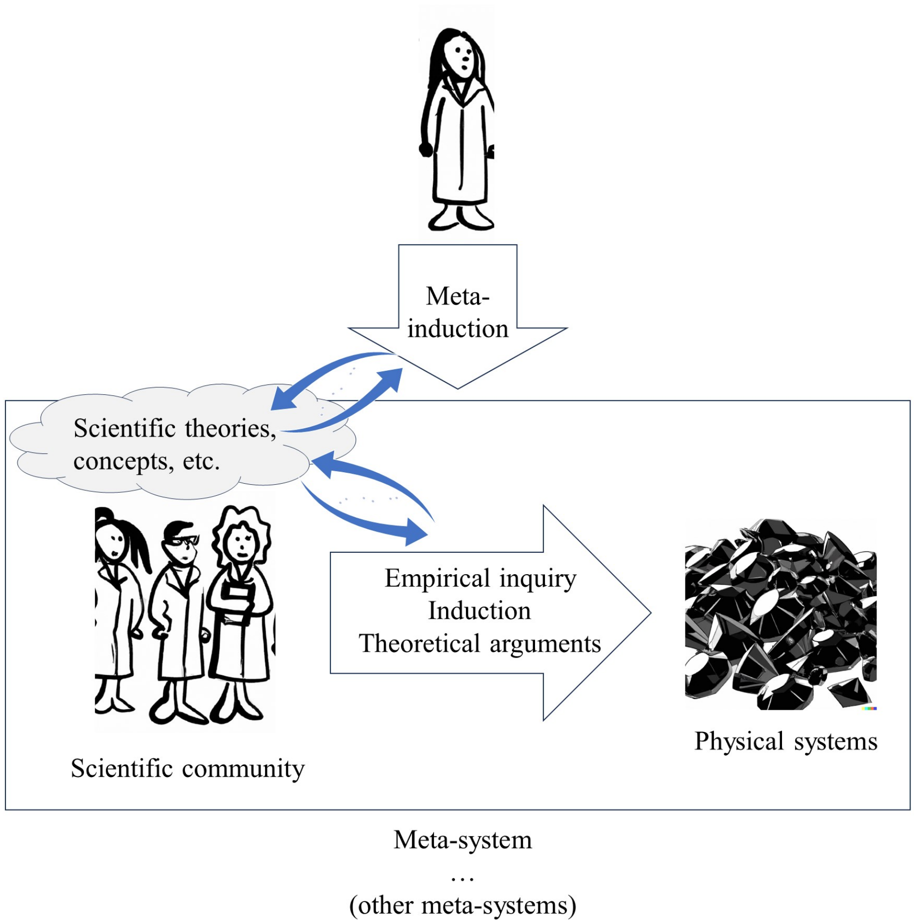

Fig. 1 Meta-inductive reasoning.

past theories constructed during a leap year tells us nothing about the success of the theories that would be constructed during 2028. A minimal criterion is that in order to be projectable, a classification of theoretical arguments has to be based on similarity between factors that demonstrably contribute to the empirical success of the theories.

To identify such factors, let us start by noting that in the proposed account, theoretical arguments are part of the overall meta-system. This meta-system includes both the scientific community and the physical system being investigated. Thus, there would be many possible classifications, depending of various epistemic, methodological, formal, and empirical considerations. In particular, some classifications would be based on the 'human' side of the meta-system, i.e. on the knowledge, beliefs and concepts held and employed by the scientific community. Other classifications can be based on conjectured properties of the physical systems.

Notably, in many cases, there may not be a clear-cut separation between different types of considerations. Due to theoretical holism, a given theoretical argument can often be understood on one reading as based on certain concepts that constitute the theoretical framework, and on another reading as relying on empirical or physical properties of the described systems. Einstein's principle of equivalence, for example, has been the subject of many arguments and accounts, presented as either empirical principle, *a priori* principle, methodological principle or a formally defined one (on historical and recent debates see Fletcher & Weatherall, 2023; Knox, 2013; Lehmkuhl, 2021; Norton, 1985; Read, Brown, & Lehmkuhl, 2018). Or, as another example, the principle of indifference (assignation of equation probabilities to different possibilities at the absence of evidence), that can be given not only many epistemological readings (Eva, 2019), but also different mathematical implementations that would reflect on actual applications of probability theory (Drory, 2015). Theoretical considerations might therefore generally be subject to significantly higher degree of underdetermination compared to other kinds of considerations. The point of meta-inductive reasoning involving theoretical arguments is not to deny this kind of theoretical holism and the resulting underdetermination, but rather to point out that nevertheless, a projectability judgment would have to take a stand here, identifying a set of theoretical arguments and accounting for it or interpreting it in a certain way based on a particular reading, from among the many possible ones.

Our concern is with the justification of judgments on the projectability of meta-inductive arguments. The name of the game is empirical adequacy, a criterion which serves at the same time as the criterion that provides justification for established and accepted theories, and also the bar that future theories will have to clear. A useful notion for the incorporation of this necessary forward-looking dimension, is 'theoretical viability' (Dawid, 2013, 2019), that adds to the empirical adequacy also the capacity of a theory to adequately represent the empirical data that will be collected in the given research context in the course of future scientific development (e.g., once more experimental possibilities are available).[8] Projectability judgments of meta-inductive arguments therefore aim to characterize arguments that have led to viable theories in the past, under a classification that can be projected to new theoretical arguments aimed at producing new theories of high viability. Thus, a projectability judgment is a belief on what it is exactly that was 'done right' in previous cases of successful theorizing, an attempt to draw a (cautious and tentative) lesson from past success.

To do so, however, it is not enough for a projectability judgment to appeal to any conceived similarity between the suggested theoretical method and previous successful cases. In order for the judgment to be considered rational from a naturalist point of view, the similarity should be between contingent factors that may have contributed to the generation of a viable theory, in a way that can be spelled out as clearly as

[8]In the current context, that relates to epistemic aspects of theoretical practice, the statement that a theory is empirically adequate is taken to relate to the evidence available at the given point of time. On some accounts however, most notably in van Fraassen (1980), empirical adequacy is taken to refer to all observable phenomena, including future observations, which seem to subsume the notion of theoretical viability. Note, however, that in contrast to this notion that appears an a-temporal semantic notion, Dawid's notion of theoretical viability is explicitly epistemic; it is about what scientists have reason to believe, in a given moment of time about a theory's predictive success.

possible. Identifying such factors is part of the meta-inductive process, and explicating what are these factors and how exactly they may have contributed is the basis for a good projectability judgment.

With this aim in mind, we can note that the presented scheme of meta-induction within scientific inquiry has further crucial implications on how to understand projectability judgments. Meta-systems (Figure 1) involve a dynamic interplay between the 'human side', including theories, concepts, and mathematical reasoning, and the 'physical side' encompassing the systems under investigation. Many important aspects of the inquiry are inter-relational, i.e. they integrate these two sides in a way that is often inseparable. Experimental results are arguably among these aspects, being at the interface of processes that take place in the physical world and theory-laden experimental methods. However, other aspects, such as mathematical concepts, scientific theories, and norms of theoretical practice are clearly on the purely human side of this scheme. The empirical adequacy or the theoretical viability of a given theory are both among the inter-relational aspects. Clearly, empirical adequacy of a theory is not merely a property of a theory itself, nor of the observations. Rather, it is a property of the inter-relations between the concepts and beliefs employed by the scientific community and the physical world. Being an inter-relational property, it must also be accounted for as such.

The first implication of the inter-relational nature of empirical adequacy is that projectability cannot rest solely on similarity between aspects that purely belong to the human side of the meta-system. Such aspects cannot by themselves account for past empirical adequacy and are therefore unable to justify trust in viability of suggested theories. Such aspects are ones that pertain solely to components of theories, such as formal, conceptual, or abstract ones. In order to be projectable, any classification or notion of similarity used in meta-inductive arguments has to have inter-relational basis, i.e., they have to refer to specific ways in which theoretical concepts relate either to the world, or to elements such as observations that have a physical component.

There are several ways in which projectability judgments can refer to inter-relational classifications. One way is by identifying similarities that, instead of formal concepts, pertain to patterns of conjecture and inference used in theoretical arguments. The role of such patterns in allowing for a naturalist conception of meta-inductive arguments can be seen as analogous to that of natural kinds (in the pragmatic, naturalist understanding) in inductive reasoning. Just like natural kinds reflect contingencies attributed to nature, these patterns reflect contingencies in the scientific process. Moreover, such patterns are never purely deductive. They typically integrate theoretical reasoning with evidence in many possible explicit and implicit ways, and are therefore inter-relational.

It is here that the naturalist privileging of evidence becomes relevant. Theoretical conjectures are most projectable when they exhibit similarity in how they are motivated by evidence. The clearer these motivations are, the higher the degree of projectability. Notably, the way a theoretical argument draws its motivation from evidence may sometimes become clearer in retrospect, when it is illuminated by the context of other theoretical arguments (more on that below).

In many cases, however, no clear relation between the theoretical methods in question and the evidence can be established. (Take, for example, theoretical frameworks like group theory in physics, whose projection from one case to another may not rely on empirical data in any evident way). Yet, these cases are not necessarily non-projectable. The minimal bar of reliance on inter-relational properties can still be met by connecting conceptual structures to conjectured contingencies in the world, e.g. using a representation relation.[9] Here, the degree of projectability will be related to the plausibility of this connection, judged in light of existing background knowledge. In such cases, the theoretical side must plausibly relate to a hypothesized structure or pattern in the world, even if this relation is mediated by more abstract considerations.

As we shall see in some examples below, these conditions are far from being trivial. In fact they can filter both philosophical accounts and suggested scientific accounts of the success of certain theoretical methods, and have potential implications on theory construction and debated philosophical issues.

In summary, in a naturalist view of the scientific process, projectability judgments are judgments of the plausibility of given theoretical methods to advance theories of high viability, based on similar past cases. More precisely, they have to depend on inter-relational features of these past cases, that tie theoretical adequacy to evidence or to contingent world features, where the former is preferred over the latter. In this way, the scientific role of considerations that are formal, mathematical, and abstract can be understood without appealing to apriorism, by transparently highlighting the way such considerations are inspired, motivated and justified based on lessons from past science. This view further aims to use relatively consensual basic scientific standard to strike a balance between the view that methodological lessons from past science can make some theoretical methods and conjectures better justified than others, and approaches that emphasize the importance of creativity and open-mindedness in theory construction.

Before turning to examples, a short comment on the retrospective nature of projectability judgments is in place. Projectability judgments evaluate past scientific successes and failures, requiring a selective interpretation of messy historical processes involving various contingent factors. Such judgments tentatively identify scientifically valuable elements while constructing an idealized picture of theoretical development. Like in standard inductive reasoning, they reflect revisable knowledge, highlighting how our understanding of past science may depend on current theories (more on this in §5.)

[9] The naturalist would avoid imposing one overarching definition of representation on a wide range of cases, and instead aim to define it in a context dependent way, based on the role of the notion in established theories. A more detailed account of representation warrants separate treatment.

3.4 Example: projecting the applicability of differential equations

Numerous physical phenomena, such as motion and changing currents in electric circuits, are successfully described in physical theories using ordinary differential equations dependent on the time variable (t-ODEs). During the 20th century, this modeling technique was exported to fields such as population dynamics and economics, and later to the field of systems biology. In this section we shall use this example to demonstrate how even a relatively simple theoretical method can be accounted for in radically different ways, and how a naturalist understanding is related to the projectability of the method.

To understand this transfer as meta-induction, we view physical theories employing t-ODEs as background theories guiding the construction of theories in new domains.[10] We can interpret this meta-induction through two distinct philosophical lenses: a non-naturalist account and a naturalist one. Contrasting these perspectives reveals that the naturalist account better supports the theoretical practice of meta-induction, specifically in how it satisfies projectability criteria outlined in §3.3.

Non-naturalist accounts typically focus on the human or the conceptual components of the meta system (left side of Fig. 1). In the context of differential equation, this approach is clearly exemplified by McCloskey (1991), whose analysis views science as a specialized form of rhetoric, not inherently different from other rhetorical forms. In opposing conceptions described as positivism and modernism in the philosophy of economics, McCloskey advocates a view of science that is at odds with naturalism, notably by rejecting prediction as a defining scientific goal (McCloskey, 1983). Dynamical models and differential equations originate in this account from metaphors and narrative frameworks, both understood as rhetorical strategies. Note that this view , according to McCloskey, is not in conflict with the formal nature of the theories, but rather with the view that they are empirically based.

In contrast, a naturalist approach would first clarify why differential equations successfully apply in certain cases in physics and would then identify relevant similarities between these established successes and potential new applications. Einstein's reflection on Newton's legacy provides an illustrative naturalist explanation, according to which '[t]he differential law is the only form which completely satisfies the modern physicist's demand for causality.' Differential equations express the way in which 'the state of motion of a system gives rise to that which immediately follows it in time' (p. 255) (Einstein, 1927, p. 255).

On a naturalist reading, Einstein's 'demand for causality' stems from contingent background theories rather than universal principles. The successful use of differential equations in physics relies on identifying quantities whose rates of change exhibit causal dependencies specific to each studied system.[11] In this sense, Einstein's view

[10] For recent discussions of knowledge transfer from physics to ecology and economics, see Donhauser and Shaw (2019); Gandolfo (2008); Knuuttila and Loettgers (2017).

[11] An overview of the discussion on the relation between causation and differential equations in mechanics is found in Lange (2009).

relates the projectability of differential equations to the causal relations (which might be observable only indirectly or even not at all) that are conjectured based on background knowledge. The argument can become even more projectable if it is these quantities that have measurable impact in which the scientific community is interested (even though they may provide, at most, a very partial and coarse-grained description of the systems). For instance, Volterra's population models (Volterra, 1928) utilize t-ODEs because predator-prey interactions produce clearly measurable and causally interconnected population changes.

The crux of this section is that there is a specific sense in which the naturalist account has a distinct advantage. To see this, note first that although differential equations have broad applicability, their usefulness has clear limits. Fields like population biology, systems biology, and economics frequently employ alternative modeling techniques, such as discrete models, stochastic models, or agent-based models, that are conceived as better capturing the dynamics of certain systems compared to t-ODEs. The clear advantage of the naturalist accounts is that they have the resources to delineate conditions under which differential equations are genuinely applicable. They can potentially tackle the question of which systems should be described by t-ODEs and which ones by alternative models, exactly because they attribute successful cases to inter-relations between theory and target systems.[12] Conversely, approaches that analyze the theoretical use of differential equations solely based on their role in a conceptual or rhetoric framework may provide no systematic way to define such limits. By accounting for the applicability of differential equations only in terms of the conceptual/human side of the meta-systems and disengaging from the evidence and conjectured properties of the systems of interest, such accounts might be unable to provide justification for judgments on the potential applicability of differential equations to given new systems and domains. Note that the same would be true for approaches that appeal only to formal aspects of t-ODEs (even if they are not explicitly non-naturalist). This is an important point that will be revisited in the examples provided in the next section.

4 Exploratory applications: Meta-induction in contemporary debates

The examples in this section aim to demonstrate the relevance of the framework of the projectability of meta-inductive arguments to central open discussions in the philosophy of science. §4.1 describes the debate on non-empirical/meta-empirical considerations in theoretical physics and discusses the relation of the suggested account to existing conception of meta-induction in this context. §4.2 then takes a more concrete demonstration, analyzing a debate on invariance argument within physics, suggesting to understand it as a case of a 'new-riddle of meta-induction' in which projectability judgments have to play a key role. Section 4.3 then moves away from physics and shows how projectability judgments on meta-inductive arguments can add a crucial aspect to ongoing debates on the theoretical practice of model transfer in the special sciences.

[12] For example, the continuous time parameter of differential equations is taken to capture causal relations between different generations. It is inadequate to describe Population dynamics of salmon, whose generations do not overlap, and it thus modeled using discrete-time models (see Brauer & Castillo-Chavez, 2012).

§4.4 places the discussion on projectability in the broader context of meta-inductive justification in the philosophy of science.

4.1 Projectability of theoretical methods in fundamental physics

Current fundamental physics faces a unique epistemic situation (or, according to some, a crisis) in which the development of new theories, their justification, and debates on the choice between them are carried out given an exceptionally small amount of relevant direct evidence, and empirical testing often comes decades after a theory has been suggested. One result of this situation is a plethora of theoretical endeavors aiming to go beyond established theories, that are often motivated by (and constructed using) mathematical considerations, while the possibility of experimentally testing their predictions remains unclear for long periods.

The debate about this situation might sometimes seem to be between two radical possibilities: one advocating for a categorical rejection of a wide range of ongoing theoretical endeavors (such as string theories and or multiverse theories) as non-scientific (Ellis & Silk, 2014; Hossenfelder, 2018), while the other calls for a revision in the epistemology of science.[13] In recent philosophy of physics, the situation is reflected in more refined discussions characterized by increasing emphasis on questions of methodology, justification, and assessment. Recent discussions concern the general status and general role of principles and theoretical virtues (Crowther, 2021; Crowther & Rickles, 2014; Holman, 2014), the analysis of suggested individual principles,[14] and a range of opinions on non-empirical justification and assessment. (Dardashti et al., 2019).

The major goal in this context is to unify gravity and non-gravitational interactions (typically anticipated as a theory of quantum gravity), aiming not only at conceptual unification but also at understanding phenomena at Planck-scale conditions—extremely high energies and minuscule spatial and temporal intervals. Indeed, in pursuing this goal physicists most often use theoretical virtues, principles, and methods that are similar to those employed in the formation of established theories, implicitly appealing to meta-inductive reasoning. However, the theoretical guidance for this task depends significantly on which theoretical principles are being projected. For instance, extending principles like symmetry and unification from the well established Standard Model of particle physics would lead theorists toward a certain class of research projects. Alternatively, emphasizing principles like background independence (roughly speaking, the idea, associated with general relativity, that spacetime structure should emerge from the theory itself rather than being assumed at the start; see Read, 2023; Smolin, 2006) and discreteness (the notion, drawn from quantum theory , that space, time and relevant physical quantities have a fundamentally discrete structure at small scales), would encourage entirely different research paths. The crucial point here is that the choice of principles to project and the choice

[13] Such as promoting theory assessment based on non-empirical considerations (Dawid, 2013, later reformulated using the less radical notion of meta-empirical considerations, see references below) , or calling for the rejection of falsifiability (Carroll, 2019).

[14] Background independence (Smolin, 2006), naturalness (Borrelli & Castellani, 2019; Fischer, 2023, e.g.,), and the holographic principle (Dieks, van Dongen, & de Haro, 2015) are just a few examples.

of established theories (from which principles are projected) have significant implications for the resulting research programs. The question of projectability is therefore not only philosophical; it directly influences theoretical practice.

A notable attempt to tackle these issues is by Dawid (2013, 2016), who presented an account of justification in the context of these questions based on an explicit appeal to a certain form of meta-inductive arguments (employed a as part of a wider framework of interrelated arguments for meta-empirical confirmation). In Dawid's meta-inductive arguments , the belief in the theoretical viability of suggested theories is justified based on the empirical success of theories from the same research program or theories that share a theoretical strategy. Thus, the empirical success of the standard model of particle physics provides epistemic support for string theory which is conceived as extrapolating some core theoretical methods of the former (principally, separation between energy scales, gauge symmetries, and the way they are employed for unification). These claims resulted in an exchange concerning the epistemic force of Dawid's conception of theory assessment, his notion of meta-induction, and the validity of his conclusion (Chall, 2018; Dawid, 2022; Menon, 2019; Smolin, 2014).

The approach to meta-induction presented in the current paper, together with the associated notion of projectability, can contribute to the efforts to articulate a refined approach to the debates on the epistemic situation in fundamental physics. It offers a unified framework that can accommodate large parts of these discussions, from instances of Dawid's meta-inductive arguments to the literature on physical principle and theoretical virtues. It clearly emphasizes that the source of epistemic authority in all of these cases is the empirical success of established theories. While the framework is broad, the concept of projectability allows for a refined judgment of theoretical viability, based on the relevance of the similarity between theoretical methods applied in ongoing and past theorizing to the formulation of a theoretically viable and empirically successful theory in the past.

A potentially significant implication of the suggested account on the debate is the claim that a formal similarity by itself cannot support a projectable meta-induction. A successful application of, say, group theory or principle fiber bundle formalism, does not provide epistemic support for theories that are constructed using similar formalism or extensions of it, unless this formal resemblance is shown to constitute a part of a broader similarity between patterns of inference that relate to the evidence, or at least to a conjectured physical contingency. In this sense reconciling empirical scientific (or naturalist) standards with the kind of mathematical reasoning abundant in contemporary physics, is not a trivial matter.

This difficulty underlies Steiner's (1998) anti-naturalist argument based on the successful applicability of mathematics to theoretical physics. Steiner, who did not refer explicitly to meta-induction, regarded any form of mathematical reasoning as essentially anthropocentric, and hence, unprojectable from a naturalist point of view. The view presented here acknowledges this difficulty, but also offers a way to avoid Steiner's anthropocentric conclusion. The existence of this non-projectable classification of arguments, does not preclude the existence of a projectable characterization of the same arguments. Thus, Steiner's criticism should urge the naturalist to look for such alternative, projectable, accounts of mathematical forms of reasoning.

On the more practical level, this approach suggests that some existing arguments for meta-inductive justification should be approached with a careful attitude. According to Dawid's account of meta-induction, the empirical success of a theory can support meta-inductive justification for theories from the same research program, or those that share theoretical strategy or meta-level hypotheses. The current analysis, however, suggests that the justification such arguments can provide depends on spelling out what exactly are the projectable factors—which cannot be merely shared formal frameworks—that group theories under research programs or theoretical strategies. Thus, while Dawid's notion of meta-inductive arguments does fall under the notion of meta-induction presented in the current paper, applications of his argument could in principle be found out to be non-projectable.

The requirement for projectability thus urges for a reexamination of the justification of formally motivated projects, and it can help in prioritizing among the numerous suggested theories and research programs that aim to go beyond the established theories of general relativity and the standard model of particle physics. Tackling this task, however, is an intricate matter, and there are no easy overarching solutions to be expected. There is no clear borderline between formal considerations, empirical considerations, and ones that appeal to unobservable contingencies. Naturalness arguments, symmetry arguments and background independence are just few examples for arguments that can be interpreted in various distinct ways that combine different proportions of the different kinds of considerations. In order to make judgment on the projectability of a theoretical argument of this kind, its conceptual ancestry has to be examined, namely, the heuristics of past applications of similar arguments need to be recast in the most projectable way. This is a historical, philosophical and technical exploration that can only be conducted case by case. The projectability of suggested arguments would be based on the similarities to the reconstructed version, that are relevant in a clear way to the empirical success.

4.2 Invariance arguments: a new riddle of meta-induction

The cases described in the previous section are mostly ones in which competing principles lead to distinct research programs as they are projected from different established theories. A different yet interesting case involves competing methodological readings of the same theoretical methods. These cases can be seen as instantiating a 'New Riddle of Meta-Induction'. Here, certain theoretical methods underlying established theories can be characterized or classified in various ways. These distinct characterizations, each plausible and internally consistent with the empirical success of the methods, can nevertheless lead to conflicting research programs when projected forward.

To demonstrate this using a concrete example, let us consider invariance arguments in physics. Invariance arguments have a central place in the toolkit of the contemporary theoretical physicist, including a major role in the formulation of contemporary theories of gravity and particle physics. Such arguments typically constrain or extend theories in light of 'symmetry principles', i.e., by imposing a requirement that some theoretical structure (usually dynamical structure) would remain unaltered under certain mathematical operations (often called 'symmetry transformations', with the terms 'symmetry' and 'invariance' often being used interchangeably). In the philosophy of physics, many debates revolve around the view of invariance as a manifestation of objectivity (Castellani, 1995; Kosso, 2003; Nozick, 2001), symmetry as a guide to ontology (Baker, 2010; French, 2014; Ladyman & Ross, 2007; López, 2023; North, 2021; Rickles, 2008), and the observability of symmetries (Brading & Brown, 2004; Greaves & Wallace, 2014; Kosso, 2000; Teh, 2016).

While the focus on these interpretational debates might create the impression that the heuristic role of invariance is well-established and widely accepted, a closer look reveals that symmetry considerations can be (and, in fact, are) described in various different and sometimes contradicting ways. These include characterizations in terms of enlargement of the symmetry group of given theories with the aim of unification, reduction of interactions to a fiber bundle geometric framework, localization of global symmetries, or the construction of theories whose symmetries guarantee (via Noether's theorem) local conservation of certain quantities. While it is not clear at all whether these characterizations correspond to distinct views of reality, they can be associated with different ways of interpreting the formalism, identifying certain notions within it as more fundamental than others, and coordinating it with possible observations.

Within well-confirmed theories these characterizations are seemingly harmonious, and under certain conditions even formally equivalent. This is true for different manifestations of the 'gauge argument' and possibly to the application of local-symmetries in general relativity, (see for example Martin, 2002, 2003). However, this is not the general case for all physical theories. When it comes to suggested theories (such as particle physics beyond the standard model and theories of modified gravity), the different schemes diverge into different methods (or different symmetry principles), that are employed in competing theoretical enterprises. While in some cases there is an overlap between these considerations, in many other cases they lead to different, contradicting theories.

As a concrete example, consider the attempts to apply the concept of gauge to gravitational theories. This project broadly aims to project to gravity the theoretical framework of gauge symmetries that characterizes the non-gravitational interactions. With this aim, Utiyama (1956) suggested to construct general relativity by gauging the Lorentz group. Shortly after, Kibble (1961) noted that the standard requirement that *every* global symmetry should be made local leads to the gauging of the Poincaré group, implying a different (torsionful) spacetime geometry and a deviation from general relativity (which is currently practically undetectable) due to the coupling of spinors to this torsion. Other unification programs further extend the gauge group together with the geometrical structure (Hehl, McCrea, Mielke, & Ne'eman, 1995). Understanding these theories using a geometrical description of gauge can lead to coupling prescriptions that would further alter the empirical content (Delhom, 2020).

The projectability of different characterizations of invariance arguments that were employed in the construction of well established theories can therefore reflect on the assessment of suggested theories constructed using other invariance arguments that fall under these characterization. It is easy to realize, even without full engagement with the details of these theories, that this situation is an exemplification of the significance of the notion of projectability of alternative characterization of past theorizing, i.e., a 'new riddle of meta-induction'. This example demonstrates how beyond philosophy of science, the issue of the projectability of meta-inductive arguments can have implications within theoretical physics.

Tackling the issue and applying the current account to establish judgment on which characterization of invariance arguments is the most projectable one will require thorough engagement with the theoretical details. A preliminary outlook would suggest that purely formal characterization (e.g., based on a principal-bundle/frame-bundle framework, or a formal localization requirement) are of low projectability when compared, for example, with a reading of invariance arguments as a pattern of generalization from local evidence (Hetzroni & Read, 2024). Conserved quantities can also form projectable contingent factors. Here, an argument based on measurable conserved quantities is clearly more projectable than one based on conjectured ones (yet, the latter one can also be projectable in some cases).

Finally, it is interesting to note that accounts of symmetry and invariance in physics that portray these concepts as heuristic aids often describe themselves as deflationary. The above discussion, however, suggests that a finer philosophical analysis of the heuristics can have significant consequences, possibly more than an investigation of the formal aspects of these concepts and the relations between them necessitated by certain mathematical frameworks.

4.3 Model transfer in the special sciences

Many scientific fields such as systems biology, neuroscience, and economics have been increasingly adopting quantitative approaches by applying various mathematical modeling techniques. The transfer of models and modeling principles across different domains is a common practice in this context. Many recent philosophical discussions have concerned the justification of model transfer, the identification of the object of transfer, and the place this practice takes in scientific progress (see Herfeld, 2024, for a recent review).

Of particular importance is the question of the empirical grounding of model transfer and the interplay of empirical considerations with formal and conceptual ones. These questions are commonly addressed either through the framework of analogies (Hesse, 1966, 2017), or that of computational/formal templates (Humphreys, 2002, 2004, 2019). These frameworks have been applied to various cases in physics, biology and 'econo-physics'.

The philosophical discussions on the justification of models and model transfer focuses mostly on the relationship between a model and its target systems. The two frameworks generally depart in this respect (Knuuttila & Loettgers, 2020): analogy accounts typically use the notion of representation, while formal templates are based on model construction assumptions. Justification, in this latter approach, is based on the validation of the construction assumptions for every given application of the model template (Humphreys, 2019). Yet in many cases, many aspects of the target system are neither observable nor understood in advance. In such cases, when constructing models and judging their plausibility, little can be said about the possibility of a representation relation, or the validity of construction assumptions. Thus, by focusing primarily on the relation between the model and its target system, both approaches neglect the historical process of model development. This diachronic aspect of science is where the function of models (and hence also their justification) as part of the practice of theory construction becomes relevant. (Hartmann, 1995).

The suggestion to be made here is that justification of model transfer in its historical context is better accounted for if this practice is understood as a meta-inductive argument. The empirical success of a model in a given context motivates a retrospective examination of the construction of this model, aiming to understand it as based on projectable factors. These are primarily empirical ones, and also transparently motivated conjectured contingencies, that are invoked when empirical factors do not provide a full account. These projectable factors can be representation relations in some cases and construction assumptions in other cases; judgments on the degree of their projectability has to be made on a case by case basis, based on specific ways they relate to available evidence and existing knowledge. These judgments, on the projectable factors that contributed to past modeling and model transfer, form a body of methodological knowledge that can be employed, via enumerative meta-induction, to justify (or criticize) cases of suggested and ongoing transfer of models and modeling principles into new domains. In some cases this approach may capture the ways scientists change their practice based on the successes of theoretical practice in other domains. In other cases this approach can support the assessment of competing modeling strategies.

The meta-inductive approach to model transfer can pragmatically accommodate elements used in currently suggested approaches, but it is also distinct from them. The enumerative aspect is where the meta-inductive approach goes beyond analogical reasoning, acknowledging conceptual methodological frameworks that develop through many cases, not just as a matter of pairwise analogies. In this sense, meta-induction resembles the template approach. However, while templates are conceived primarily as formal, in the meta-inductive approach the basis for a projectable transfer is empirical and contingent methodological factors understood on the backdrop of the specific epistemic situations in which the different models are employed. This approach can provide a better understanding of domain-specific methodological commitments (that cannot be captured by the general template-based approach according to some critics, see Herfeld, 2024). According to the current account the projectability of such commitments depends on the extent to which they can be considered as inter-relational properties of the meta-system (§3.3), that are relevant for the empirical success of the model. Detailed analysis of specific examples is a task for another day.

4.4 Meta-induction beyond theory construction

Schurz (2019) presents an account of meta-induction that significantly resembles the account provided in §3.2, being similarly based on an interplay between two sides: a social aspect and a natural one. The social side consists of players that represent different prediction methods. They compete by generating predictions for a sequence of events. Each player's past predictive successes are continuously evaluated, and their performance scores determine their relative weights or influence on future meta-inductive predictions. The central player, the meta-inductivist, updates predictions by combining the methods of successful players, weighted according to their relative past success. This allows the meta-inductivist to consistently follow the most effective available methods over time. Thus, competing methods are justified based on their successful predictions, providing an 'optimality justification' for assessing the methods and choosing the optimal one.

The goal of Schurz's account is to provide a unified epistemic framework and to resolve the problem of justifying inductive reasoning without relying on circular arguments or unjustified assumptions. Schurz aims to provide a rational and practical justification for the continued use of inductive methods, highlighting adaptability to empirical outcomes. This approach seeks to maintain rational inquiry by establishing a stable yet flexible foundation for inductive practices.

Despite the different goals of Schurz's account and the current one, it is possible to outline two different ways in which they may complement each other. For one, thus far we have applied meta-induction to evaluate specific theoretical methods without attempting to justify meta-induction as a general practice. It can be instructive to examine whether Schurz's account, in particular as applied for 'theory-generating abduction' (Schurz, 2024, §10.1) would imply that in certain contexts, projecting successful theoretical methods may indeed be optimal to achieve instrumental success.

Conversely, the current discussion may suggest that the need to make projectability judgments over meta-inductive arguments goes beyond cases of mathematically-guided theory construction such as the ones mentioned in the above subsections. Scientific predictions are the products of theories, which in turn are subject to various forms of underdetermination. Thus, generally we would not expect a single and straightforward way of clustering cases of successful predictions into instantiations of 'prediction methods'. This aspect is in line with Schurz's (2024) question about rules of theory-construction for projecting components of theories into different theoretical frameworks. A closely related and more consequential concern about Schurz's meta-inductive justification of induction was recently raised by Bakshi (2025), arguing pessimistically that an identification problem and an underdetermination problem 'are serious and possibly fatal to the meta-inductive approach'.

The current paper may hint that naturalist epistemology of science may show the way to tackle these problems. If applying Schurz's scheme to actual scientific cases of competing prediction methods essentially involves some form of underdetermination of these methods, projectability criteria may be the way to overcome this obstacle, as they can justify a choice among underdetermined possibilities. Such a solution, if based on the current account, would depend on the background theories relevant at any given scientific context, and would therefore be domain dependent.

5 Concluding reflections

Current discussions on the justification and assessment of theoretical practices involve a range of concepts such as the pursuitworthiness, theoretical viability, potential fruitfulness, and estimated material and cognitive costs. These concepts allow philosophy of science to contribute to a rational reflection on scientific practice and decision making. However, neither the costs nor the fruits of a theory are known in advance. Therefore, any of these concepts represents a factor of uncertainty. While the history of science can serve as one of the main guides in estimating these factors, there is no clear and unique way to learn from it. A major reason, beyond the complex and messy nature of historical processes of theory development, is the methodological aspect of underdetermination. This underdetermination implies that in a given instance of theorizing, even after empirical success has been established, there are many ways to understand and interpret the theoretical methods at play and the way they function together. This multitude can stem from different possible epistemological viewpoints (as in §3.4), or from different interpretations of the formalism or its coordination with evidence (as, e.g., in §4.2).

This methodological underdetermination can *prima facie* provide additional support to methodological pluralism, an already popular and reasonable stance, in particular in situation where evidence is scarce.[15] Pluralist approaches, however, famously face the challenge of accommodating norms of judgment and rationality that are intended to distinguish these approaches from undesirable forms of relativism. This paper suggests that reading established theories through the lens of naturalist epistemology of science can provide support for meeting this challenge. More specifically, The paper proposes to navigate the methodological underdetermination by privileging readings of past successes that emphasize empirical extrapolation or conjectured contingencies over ones that attribute success to formal theoretical components or to *a priori* principles. Naturalist epistemology here influences theory justification indirectly, through shaping how past methods are first understood and classified, and then projected.

This point is an important addition to existing accounts of meta-induction. In Dawid's scheme of non-empirical confirmation (especially as presented in Dawid, 2016), meta-inductive arguments use the empirical success of theories to provide justification for suggested theories that are sufficiently similar. The current account notes the multitude of notions of similarity and can help identify the relevant, 'projectable' ones (§4.1). In a different context, Schurz (2018, 2019) provides meta-inductive justification for the optimality of certain prediction methods by tracking their success rates, under a picture based on an interplay between a social side and the natural side, with some resemblance to the meta-system described in §3.2. However, at least in the context of

[15] On the relation between pluralism and underdetermination see, e.g., Bonnin (2021); Longino (2002); Tulodziecki (2025).

theory construction we have seen that there is no way to determine whether two theoretical arguments manifest the same 'prediction method' without some criterion for classification of methods. Here again, the suggestion is to choose these criteria based on their projectability.

The broader context to the question of projectability is the issue of the rationality of theoretical practice. The question of scientific rationality reemerged during the historicist turn in the philosophy of science, due to the recognition of the dependence of scientific practice on changing conceptual frameworks and the failure of the traditional separation between the context of discovery and the context of justification in various cases (Nickles, 2021), in particular in what Laudan (1977) called the 'context of pursuit'. Theory construction forms a significant component of scientific pursuit. Elucidating its epistemic foundations becomes increasingly important as theory construction continues to employ quantitative methods based on abstract concepts and to push into domains where direct empirical tests are more and more challenging. By promoting a better understanding of how past successes can inform current theorizing, the framework of meta-induction presented in the current paper sketches one possible approach to meeting this challenge, highlighting a particular way in which discovery and justification dovetail and suggesting a means of learning from the history of science that is both philosophically grounded and practically oriented.

This reflective process is notably bidirectional. Understanding the way natural kinds function in inductive inferences has to take into account the process of revising existing taxonomies after discovering new species (see, e.g., Ereshefsky, 2007). Similarly, new theoretical successes can retrospectively change the way in which the workings of theoretical methods in past case studies are understood and classified, e.g. by highlighting less familiar ways in which a mathematical manipulation is related to existing evidence.

In this view, every methodological component in theoretical sciences undergoes continuous reassessment, aiming for coherence in our understanding of these methods and their relation to data, evidence, and representational concepts. In this process, the accepted answers to questions such as 'what was it exactly that Einstein did right in his development of the general theory of relativity?' continuously evolve as part of a larger bulk of methodological knowledge, whose role in grounding judgments on the projectability of theoretical methods is central to the advance of science.

This methodological knowledge is neither encapsulated in the empirical content of current theories nor in their formalism. It emerges from a scientific approach to understanding the process of science itself by a careful, piecemeal reflection on historical case studies in light of current knowledge. In this sense, methodological knowledge is fallible and revisable like other forms of scientific knowledge; it similarly acquires its fundamental justification from the empirical and epistemic achievements of the scientific process.

A potential concern naturally arises regarding this picture of ongoing methodological reexamination. Doesn't this approach, which interprets past theoretical successes through the lens of current understanding, risk falling into a form of Whig history?

The danger is that such a reconstruction might be based on imposing current theoretical frameworks onto past scientific practices, selectively highlighting factors that align with it, thus potentially distorting the actual historical process through which these methods emerged and evolve, and possibly overlooking alternative explanations or contextual factors that don't fit the current narrative. Furthermore, such accounts might lead to a teleological view of scientific progress that makes past developments seem more rational and linear than they actually were.

To address these concerns it is essential to clarify that if science is to be understood as a rational process, the reconstruction of the theoretical methodology provided in a meta-inductive argument has to have some historical basis. The general aim is not merely to come up retrospectively with an idealized methodology inspired by current science, that has nothing to do with ideas that were at play during the actual development. Although such reconstructions can be illuminating in some individual cases, widespread application of them might lead to a chaotic depiction of the scientific process, one in which scientists repeatedly stumble upon successful theories through fundamentally flawed reasoning, thus undermining any attempt to rationally draw lessons from past theoretical practice. A genuine meta-inductive approach must therefore bridge between current theoretical interests and some aspects of the actual historical development, not an entirely retrospective reimagining thereof.

For that reason, a broad and detailed historiography of the scientific process that provides a nuanced description of the historical context, the actors, the concepts at play, and the causal factors is not at odds with meta-inductive reflection on the process, it is a precondition to conducting the reflection appropriately. There is therefore no real tension between the history of science and meta-inductive reflection, at most an apparent one that stems from the different pragmatic goals of two forms of investigation, which are, in fact, complementary.[16]

Thus, in the presented account, meta-induction looks at the history of theoretical development through the lens of conceptual frameworks that pervade contemporary science. In this scheme, reflecting on the *projectability* of meta-inductive arguments provides a way in which critics, internal and external to science, can contribute to the amendment, correction and reconsideration of the conceptual frameworks, even at the stages before new evidence is available, and through a moderate and gradual process, rather than a Kuhnian revolution. This is made possible in virtue of a 'methodological knowledge' acquired through constant meta-inductive reflections on past scientific progress. Conceiving methodological knowledge as theory-laden on the one hand and manifesting broad scientific standards (whose fundamental significance in science is relatively uncontroversial) could be a way of understanding rationality as a concept that is mostly internal to science, a possible golden mean between adopting a full methodological anarchism of the kind advocated by Feyerabend, and enforcing on science an external concept of rationality that is foreign to its practice.

[16]Lakatos (1970) presents a somewhat similar view in defense of the picture in which methodologies and their notions of rationality are being tested based on their capacity to provide a rational reconstruction of science. See also discussion in Hacking (1979).

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