# Conceptual Progress in Science: Cognitive Enhancement and Pragmatic Optimization*

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**Abstract**

This paper focuses on the nature of conceptual progress in science. Analyzing five historical episodes of conceptual progress in science, I will show that none of the existing philosophical theories of conceptual progress can make sense of all these cases. I will argue that this is because these theories try to capture conceptual progress as a single type of improvement. Instead, building upon recent cognitive science, I will propose a novel cognitive-pragmatic theory of conceptual progress that understands this phenomenon as involving two evaluative dimensions: cognitive enhancement and pragmatic optimization. While the former dimension assesses concepts in terms of their general cognitive utility, the latter assesses their optimization to the specific goals of the relevant scientific community. We will see that, thanks to these two dimensions, this theory is able to adequately characterize the diversity of conceptual progress exhibited by these historical episodes.

## 1 Introduction

Scientific progress involves the improvement of many different epistemic products of scientific activity, such as, theories, methods, practices, models, and concepts. The focus of this paper will be on the improvement of scientific concepts. Intuitively, scientific concepts seem to become better and better with the advancement of science, so that contemporary scientists are able to categorize phenomena in a more coherent way than before, employing concepts that are broader and more precise than their predecessors. This kind of improvement in scientific concepts has been long recognized by philosophers and scientists alike, who often refer to this phenomenon as 'conceptual progress'. Despite

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the strength of the intuition behind this phenomenon, philosophical discussions over scientific progress have not focused so much their attention on conceptual progress. This lack of attention is unfortunate, because, as I will argue in this paper, the few theories available in the literature cannot really make sense of the diversity of conceptual progresses that the history of science exhibits.

In this paper, I will develop a theory of conceptual progress that adequately characterizes this diversity. I will do that by focusing my attention on five historical episodes of conceptual change in science that have been intuitively characterized by scientists and philosophers alike as instances of conceptual progress. The five historical episodes that will be the center of my philosophical analysis are the Copernican Revolution, the development of the notion of IMPLICIT MEMORY, the changes in the conceptualization of NATIONAL WELL-BEING, the development of the ABSTRACT GROUP concept, and the formalization of the notion of ALGORITHM.

I will first analyze these five historical cases of conceptual progress through the lenses of three influential philosophical theories of conceptual progress in science, i.e., Laudan's problem-solving theory, Kitcher's reference potential theory, and Brigandt's epistemic aim picture. We will see that none of these theories is able to adequately characterize all the aforementioned historical episodes of conceptual change as clear instances of conceptual progress. I will then argue that the main issue with these theories is that they understand conceptual progress in science as a single type of improvement. Instead, building upon the empirical findings of recent cognitive science, I will propose a novel cognitive-pragmatic theory of conceptual progress that understands this phenomenon as involving two different evaluative dimension: a cognitive dimension, which I will call cognitive enhancement, and a pragmatic dimension, which I will call pragmatic optimization. While the dimension of cognitive enhancement assesses concepts in terms of their general cognitive utility, the dimension of pragmatic optimization assesses their optimization to the specific goals of the relevant scientific community. We will see that, thanks to these two dimensions, the cognitive-pragmatic theory is able to adequately assess all the aforementioned historical episodes as clear instances of conceptual progress.

In Section 2, I will intuitively characterize conceptual progress in science and I will present the five historical episodes of conceptual progress at the center of my analysis. In Section 3, I will survey three existing philosophical accounts of conceptual progress in science, i.e., Laudan's problem-solving theory, Kitcher's reference potential theory, and Brigandt's epistemic aim picture. I will show how none of these theories can account for all the historical episodes under focus. In Section 4, I will instead present my novel cognitive-pragmatic theory of conceptual progress in science and its two evaluative dimensions. I will then demonstrate how this theory accounts for the conceptual progressiveness of all five cases of conceptual progress at the center of this paper. Section 5 concludes.

## 2 Conceptual Progress in Science

In this section, I will describe the phenomenon at the center of this paper, namely, conceptual progress in science. I take conceptual progress to be a type of cognitive progress, i.e., progress with respect to the cognitive aims of science, i.e., truth, knowledge, understanding and the like. Conceptual progress is then a specific type of cognitive progress, namely, the type concerned with the improvement of scientific concepts.[1]

Let me stress already that I do not assume any specific philosophical standpoint about what cognitive progress in science ultimately consists of, i.e., whether, to mention the main contemporary options, it ultimately can be identified with progress in knowledge (Bird, 2007), truthlikeness (Niiniluoto, 1984), understanding (Dellsén, 2016), or problem-solving (Kuhn, 1970; Laudan, 1978; Shan, 2019). In this paper, I will be concerned only with conceptual progress, understood as a specific type of cognitive progress, and with its specific characteristics, not making any assumption about the ultimate nature of cognitive progress in science.

As I said, I take conceptual progress to be the variety of scientific progress that pertains to how scientific concepts improve with time.[2] This variety has been recognized as an independent component or dimension of scientific progress in several philosophical accounts of progress (e.g., Laudan 1978; Kitcher 1995).[3] A striking feature of conceptual progress is that the improvement of our scientific concepts seems *prima facie* logically independent from empirical progress, in the sense that we can make conceptual progress without making any empirical progress, and *vice versa*.[4] In addition, conceptual progress seems also intuitively independent from theoretical progress, in that not all improvements in the concepts used by scientists imply progress in the relevant scientific theories (and *vice versa*). This independence is particularly interesting philosophically, because it makes conceptual progress a type of scientific progress suitable for all the stages

[1]Other types of cognitive progress might include, for instance, explanatory progress, empirical progress, systematic progress, methodological progress, representational progress, and theoretical progress.

[2]From now on, I use 'scientific progress' or, simply, 'progress' as a shorthand for cognitive progress in science. It should be still kept in mind that in this paper I am only concerned with (a specific sub-type of) cognitive progress and not with any other type of scientific progress (e.g., social, technological, institutional, etc.).

[3]It should be noted that, in the more historically-minded literature in philosophy of science about concepts, authors prefer to speak about 'warranted' or 'rational' conceptual change, rather than of conceptual progress. In this paper, I prefer instead to speak of conceptual progress, making explicit my exclusive focus on episodes of conceptual change in which there is a cognitive improvement and understanding conceptual change as a completely neutral term. Thus, in my terminology, episodes of conceptual progress represent a proper subset of the episodes of conceptual change, namely, the ones in which the underlying change constituted a cognitive improvement in the concepts involved.

[4]This independence from empirical progress, makes conceptual progress *prima facie* neither necessary (e.g., empirical discoveries without conceptual change) nor sufficient (e.g., conceptual progress without empirical progress) for scientific progress *tout court*. I will not delve more on this matter, as it arguably depends on the specific general theory of scientific progress one favors.

of the history of a science, even the ones in which it is unclear whether there is any stable empirical or theoretical progress. For instance, in the early stages of a given science, in which often many schools of thought are opposing one another and the shared empirical and theoretical record of a scientific discipline is not well-defined yet, conceptual progress is often invoked as (one of) the only kind(s) of progress that can be made (Kuhn, 1970; Feest, 2022). Conceptual progress is also appealed to as a sort of tie-breaker for theory choice in radical episodes of scientific change in which there seems to be no uncontested empirical evidence favoring one theory over the other (cf. Thagard 1992; Andersen, Barker, and Chen 2006). Moreover, this independence from empirical progress makes conceptual progress applicable also to sciences the empirical progresses of which are disputed, such as social and human sciences (cf. Feest 2022; Boumans and Herfeld 2022; Turner 2022), as well as to completely non-empirical formal sciences, such as mathematics and logic (see Kitcher 1984).

After this intuitive characterization of conceptual progress in science, let me list some of the episodes of scientific change that have been recognized as instances of conceptual progress. Alleged examples of conceptual progress include: the Copernican Revolution (Laudan, 1978; Thagard, 1992; Kitcher, 1995); the Chemical Revolution (Thagard, 1992; Kitcher, 1995); the dispute between Newtonian and Cartesian mechanics (Laudan, 1978); the invention of the scientific concept of TEMPERATURE (Carnap, 1950; Chang, 2004); the long fight between wave and particle view of optics (Laudan, 1978); the introduction of the FIELD concept (Nersessian, 2008); the twentieth-century evolution of the GENE concept (Kitcher, 1982; Brigandt, 2010; MacLeod, 2012; Rheinberger and Müller-Wille, 2018); several changes in nineteenth-century biological taxonomy (Andersen, Barker, and Chen, 2006); the Darwinian revolution (Thagard, 1992; Kitcher, 1995); the formalization of the notion of ALGORITHM (Gandy, 1988); the arithmetization of analysis (Kitcher, 1984); the development of REAL NUMBERS (Ferreirós, 2015); the development of the ABSTRACT GROUP concept (Wussing, 1984); the development of the concept of IMPLICIT MEMORY (Feest, 2010, 2025), the changes in the conceptualization of NATIONAL WELL-BEING (Stiglitz, Sen, and Fitoussi, 2010). The list could be further extended for pages and pages.

This (very partial) list of examples of conceptual progress clearly shows how instances of conceptual progress can be found in all kinds of scientific changes, from epoch-making scientific revolutions (e.g., Darwinian revolution, Chemical Revolution, Copernican revolution, Arithmetization of analysis) to middle-size major disciplinary changes (e.g., the introduction of the FIELD concept, the formalization of ALGORITHM), as well as in localized normal-science-like improvements (e.g., development of IMPLICIT MEMORY concept, ABSTRACT GROUP concept). Moreover, as I already mentioned, conceptual progress seems to be present in virtually all the different types of sciences, e.g., it can be found in natural sciences (e.g., biology, physics, chemistry), as well as in cognitive (e.g., psychology), social (e.g., economics, sociology), and even formal sciences (e.g., mathematics, logic). Because of the wide scope of this phenomenon, episodes of conceptual progress present us with very different kinds of changes and improvements. In order to see that, let us look more closely at what is involved in some of the examples of conceptual progress we just listed:

- **Copernican Revolution**: several philosophical accounts (Laudan, 1978; Thagard, 1992; Kitcher, 1995) stressed that the Copernican revolution is a paradigmatic example of conceptual progress in science. That is, Copernicus' conceptual system is usually considered to have represented a substantial conceptual improvement with respect to its Ptolemaic predecessor(s). This conceptual improvement is usually spelled out in terms of the remarkable simplicity and coherence of the conceptual system of the new heliocentric astronomy, which contrasts the complex convoluted system of concepts prescribed by late Ptolemaic astronomy.

- **Development of implicit memory**: the introduction of the concept of IMPLICIT MEMORY (Graf and Schacter, 1985; Schacter, 1987) has been appraised as a significant conceptual progress for late twentieth-century psychological practice (cf. Feest 2010, 2012, 2025). This is because its introduction equipped psychologists with a quasi-operationalized concept that allowed them to formulate and conduct fine-grained experiments on dissociations phenomena. In this way, the concept of IMPLICIT MEMORY acted as a sort of conceptual catalyst for the empirical study of memory systems.

- **Changes in the concept of national well-being**: in the last decades, economists (cf. Costanza et al. 2009; Stiglitz, Sen, and Fitoussi 2010) have increasingly moved from a mono-dimensional concept of NATIONAL WELL-BEING, understood as pure economic growth and measured via indicators such as the Gross Domestic Products (GDP), to a multi-dimensional concept, understood as the growth of natural, physical, social, and human capital and measured via indicators such as the "Genuine Progress Indicator" (GPI) (Daly and Cobb, 1989) or the "Human Development Index" (HDI) (United Nations, 1990).[5] This move has been interpreted as constituting conceptual progress for well-being science by economists and philosophers alike (e.g., Stiglitz, Sen, and Fitoussi 2010; Kubiszewski et al. 2013; Alexandrova 2017).

- **Abstract group concept development**: In nineteenth-century mathematics, the concept of a GROUP was defined differently in number theory, geometry, and algebra (Wussing, 1984; Gray, 2007). The step from these multiple pre-abstract concepts of GROUP to the abstract, axiomatized concept of a GROUP that we are familiar with nowadays constituted

[5]Note that the GPI and the HDI are only two popular indicator of national well-being among many others that have been proposed and discussed in the so-called "Beyond GDP" movement. For a critical survey of many popular national well-being indicators, see (Costanza et al., 2009). Note also that, despite the many philosophical and methodological differences between these indicators, they all assume that well-being is a multi-dimensional concept (cf. Stiglitz, Sen, and Fitoussi 2010; Alexandrova 2017).

a significant conceptual improvement in the history of modern mathematics (cf. Feferman 1978; Kitcher 1984). The ABSTRACT GROUP concept improved its predecessors because of its axiomatic and precise definition, its wide applicability across domains, and the related systematicity that it brought to the many applications of the concept of GROUP across different mathematical fields.

- **Formalization of the notion of algorithm**: despite its ubiquitous use throughout the history of mathematics, the concept of ALGORITHM received a rigorous characterization only with the so-called confluence of ideas of 1936 (Kleene, 1981; Gandy, 1988). What is now known as the classical notion of ALGORITHM, instantiated by formal notions such as Turing computability or general recursiveness, drastically improved its pre-rigorous counterparts with respect to the precision and the applicability of the concept (cf. Sieg 2002, 2009; De Benedetto 2021). This additional precision allowed the development of a proper mathematical theory of computability, which, in turn, allowed the resolution of several important open mathematical and logical problems.

Before progressing in our discussion, let me stress the specific role that these five historical examples will play in my argumentation. I chose these five cases because they represent paradigmatic examples of different kinds of conceptual progress that different sciences, in different times, exhibited. As such, I believe that these five cases, taken together, constitute a good testing ground for any theory of conceptual progress in science. Consistently with this specific aim, my focus in analyzing these cases will be solely on the coarse-grained large-scale conceptual progress, blurring out many historical details of the underlying scientific changes. Thus, although my idealized reconstruction of all these cases will be consistent with the historical-philosophical literature cited for each case, the reader should not expect in the following discussion the level of detail typical of a full-blown case study in historically-minded philosophy of science. As the references given in this section show, we have plenty of excellent, detailed case studies about conceptual progress in the philosophical literature. What we lack, instead, as I will argue in this paper, is a good general theory of what all these different cases of conceptual progress have in common.

These five historical examples exemplify the diversity of improvements that episodes of conceptual progress in science can exhibit. Conceptual progress can be, in fact, exemplified by conceptual systems getting simpler and more coherent (like in the case of the Copernican revolution), but also by concepts acquiring more complexity and more dimensions (like in the case of NATIONAL WELL-BEING). Conceptual progress can be a matter of systematizing and generalizing our scientific knowledge (like in the case of the ABSTRACT GROUP concept), of finding a concept that allows new possibilities to the scientific community, such as solving important open theoretical problems (like in the case of the formal notion of ALGORITHM) or, instead, of formulating and conducting new experiments (like in the case of IMPLICIT MEMORY).

An adequate philosophical account of conceptual progress in science must put some order in this diversity of improvements, explaining what all these example of conceptual progress have in common. In the next section, we will critically assess three influential views of conceptual progress in science, while, in Section 4, I will describe my original proposal on the matter.

# 3 Three Theories of Conceptual Progress

In this section, we will survey three influential philosophical accounts of conceptual progress in science, i.e., Laudan's (1978) problem-solving theory, Kitcher's (1995) reference potential account, and Brigandt's (2010) epistemic aim picture. I will critically assess each of these three theories by using the five examples of conceptual progress in science that we saw in the last section. For each of these theories of conceptual progress, I will analyze whether and how, according to the theory, these historical episodes of scientific change qualify as instances of conceptual progress.

## 3.1 Laudan's theory of conceptual progress

The first theory of conceptual progress that we are going to analyze is Laudan's (1978) problem-solving theory. Laudan understood scientific progress, in general, as fundamentally amounting to increase in the problem-solving efficacy of our best scientific theories (or, more exactly, of our research traditions).[6] According to Laudan, this increase in problem-solving efficacy can be divided in two parts, an empirical and a conceptual part, respectively pertaining to the solution of empirical and conceptual problems. If empirical problems are defined as first-order substantive questions about objects in the domain of science (Laudan, 1978, p. 15), conceptual problems are instead higher-order questions about the well-foundedness of conceptual structures, which have been developed to answer empirical problems (Laudan, 1978, p. 48).

Laudan (1978, pp. 49-54) gives us a taxonomy of conceptual problems, distinguishing between internal and external conceptual problems. Internal conceptual problems are problems that concern the well-foundedness of a single theory. These include phenomena like logical contradictions, conceptual ambiguities (e.g., lack of discrimination between phenomena or overlaps between different concepts), and circularities, i.e., foundational loops within the theory. External conceptual problems are instead problems between a given theory and other theories, methodologies, and worldviews of the related scientific community. These problems can amount to joint logical inconsistency, implausibility, or just mere

[6] Note that, in what follows, I will not talk about research traditions or about the role that they play in Laudan's theory of scientific progress. Although the relationship with the relevant research traditions constitutes, for Laudan, an important dimension of the weighting of conceptual and empirical progress of a given scientific theory (see Laudan 1978, pp. 86-92), for simplicity, I will blur-out this additional layer of complexity and the specific weighting issues involved in Laudan's theory.

compatibility (i.e., when a theory and another theory/methodology/worldview are compatible but they do not fit into a very coherent research tradition).

Laudan's theory of conceptual progress claims that a theory is conceptually progressive with respect to another theory if it reduces the number of conceptual problems.[7] Let us look at whether Laudan's theory of conceptual progress can make sense of the five examples of conceptual progress in science that we presented in the last section. The Copernican revolution is one of the first examples of conceptual progress that Laudan mentions (Laudan, 1978, p. 46) and, indeed, it seems an almost perfect instance of conceptual progress *qua* resolution of important conceptual problems. As Laudan (1978, p. 46) recalls, in fact, the bulk of criticisms faced by late Ptolemaic astronomy were of a conceptual character, including both internal conceptual problems (such as the conceptual ambiguities, overlaps, and implausibilities of its baroque system of equants, eccentrics, and epicycles) and external conceptual problems (such as the joint contradictory status of Ptolemy's assumptions on the movements of celestial bodies and the accepted physical and cosmological theories about the nature of heavenly bodies). The Copernican revolution represents, thus, a paradigmatic conceptual progress for Laudan's theory because Copernicus' theory drastically reduced the (weighted) number of conceptual problems that affected late Ptolemaic astronomy.

The case of the classical notion of ALGORITHM can also be easily characterized as involving the resolution of conceptual problems. Indeed, looking at Gandy's (1988) extended reconstruction of the confluence of 1936, we find a constellation of internal and external conceptual problems affecting the pre-formal algorithmic mathematical practice, such as the impossibility of understanding the generality of Gödel's incompleteness, as well as of solving the Diophantines equations problem, Thue's word problems for semi-groups, and, of course, the *Entscheidungsproblem* for first-order logic. All these conceptual problems were solved only with the introduction of the formal concept of algorithm, which allowed for the first time to quantify over all possible effective procedures, and the related birth of computability theory as a mathematical discipline. So far, so good for Laudan's theory.

Things become more complicated for Laudan's theory when we look at episodes of conceptual progress such as the development of the ABSTRACT GROUP concept and the changes in the conceptualization of NATIONAL WELL-BEING. The conceptual improvements involved in these two historical episodes seem in fact to revolve more around the virtues of the newly introduced concepts, rather than in the resolution of previously felt conceptual problems. In fact, in the ABSTRACT GROUP concept case, its conceptual progressiveness seem to be related with the degree of systematization that the abstract group concept allowed the relevant parts of mathematics (cf. Feferman 1978; De Benedetto 2023). In a similar way, the recent changes in the conceptualization of NATIONAL

[7] More exactly, as Laudan (1978, pp. 64-68) emphasized, this reduction has to be weighted according to the significance of a given conceptual problem for a certain scientific community. Again, I am blurring out this additional degree of complexity, focusing instead on Laudan's core idea of conceptual progress *qua* conceptual problem-solving.

WELL-BEING seem to be driven more by a positive search for a more inclusive and diverse measure of the economical well-being of a nation, than by a need of resolving an existing conceptual problem (e.g., Daly and Cobb 1989).

Nevertheless, an enthusiast of conceptual progress as problem-solving could perhaps reinterpret the virtues of the new concepts as stemming from the resolution of methodology-related external conceptual problems. Indeed, Laudan (1978; 1984) stresses several times the importance of resolving methodology-driven conceptual problems for its picture of scientific progress. In this sense, we could note that the formulation of the ABSTRACT GROUP concept "solved" the incompatibility between the informal mathematical practice based upon the pre-abstract GROUP concepts and the increasingly formal-axiomatic methodology of late 19th century mathematics (see Gray 2008). Analogously, for the case of NATIONAL WELL-BEING, a problem-solving enthusiast could argue that the conceptual change championed by the "Beyond GDP" movement resolved (or at least diminished) the tension between the reductionist, purely economical conception of WELL-BEING used by economists and the ecological, social, human, and psychological dimensions of national well-being that sociologists and psychologists have been highlighting for decades. Thus, although these two examples of conceptual progress do not seem to be well-analyzable solely in terms of resolving conceptual problems, they could still count as (possibly borderline) instances of conceptual progress for Laudan's theory.

The remaining example of conceptual progress we saw in the last section, i.e., the invention of IMPLICIT MEMORY, arguably resists, instead, any tentative reading of it as a resolution of a conceptual problem. In fact, this episode is characterized by a sort of forward-lookingness in its conceptual improvements (see Bloch-Mullins 2020), in that, as stressed in detail by Feest's (Feest, 2010, 2012) philosophical analysis of this case study, the introduction of the concept of IMPLICIT MEMORY represents a conceptual progress for twentieth-century psychology because it allowed psychologists to formulate and test empirical hypotheses about experimental dissociations phenomena. With the introduction of the concept of IMPLICIT MEMORY, in fact, the scope and nature of experimentally observed discrepancies between the performance of a subject in a recollection task and their own explicit recollection were conceptualized as stemming from the action of different memory systems. Thus, this conceptual improvement is not related to any conceptual problem that needed to be solved, but rather to a forward-looking modification of the relevant scientific practice. This example, together with the last two we discussed, highlights a significant blindspot in Laudan's theory of conceptual progress, namely, the purely negative character of its characterization of conceptual improvements. Conceptual progress according to Laudan is always determined by the resolution of known problems and, never, by some positive advancement of our conceptual tools.[8] Yet, as our discussion in this section has shown, conceptual progressiveness seems to have also a positive character, at least in some of its instances.

[8]Indeed, in Laudan's (1978, p. 68, 119-120) general comparative measures of scientific progress, the conceptual dimension plays only a negative role, while the positive role is reserved for the empirical dimension of scientific progress.

We can schematically represent how Laudan's theory applies to our five examples of conceptually progress with the help of the following table (Table 1):

| | Copernican | Memory | Well-Being | Group | Algorithm |
|---|---|---|---|---|---|
| Laudan | ✓ | × | ≈ | ≈ | ✓ |

Table 1: The results of applying Laudan's theory of conceptual progress to our five examples. The different symbols indicates three different degrees of applicability of the theory to the historical episodes: the symbol ✓ indicates full applicability, the symbol ≈ indicates partial applicability, and the symbol × stands for inapplicability.

## 3.2 Kitcher's theory of conceptual progress

The second theory of conceptual progress that we are going to analyze is Kitcher's (1995) reference potential theory. Kitcher presents his views on conceptual progress in the context of his general practice-based theory of scientific progress. According to Kitcher, conceptual progress is the dimension of scientific progress that pertains to the improvements in the language of a given scientific practice. More specifically, "conceptual progress is made when we adjust the boundaries of our categories to conform to kinds and when we are able to provide more adequate specifications of our referents" (Kitcher, 1995, p. 96).

Conceptual progress in science is understood by Kitcher as involving fundamentally two kinds of improvements: progress in the ability of our scientific concepts to track natural kinds and progress in the way in which our scientific theories manage to specify their referents. Conceptual progress is, then, for Kitcher, progress in the extension and in the intension of our scientific terms. More specifically, Kitcher's theory is dependent on the notion of reference potential, i.e., "the compendium of the modes of reference of a term" (Kitcher, 1995, p. 76). Kitcher's idea is that, in a given scientific practice, at a given time, there are often different ways of specifying the referents of a scientific term, that is, many terms have a heterogeneous reference potential that encompasses different modes of references. Conceptual progress in science, Kitcher (1995, pp. 95-105) argues, is best understood as the improvement in the reference potentials of the scientific terms of a scientific practice. A practice can improve the reference potential of a term either by abandoning a failed mode of reference or by adding a successful description (or both, as it is often the case). This improvement in the reference potential of scientific terms is understood by Kitcher as an iterated approximation to an ideal conceptual state (see Kitcher 1995, p. 106), in which the language of a scientific practice would be able to give a perfect description of its domain, referring only to genuinely natural kinds in a perfectly clear and univocal way.

Let us look at whether Kitcher's theory can account for our five historical examples of conceptual progress. Just like Laudan, Kitcher also uses the Copernican revolution as one of his first examples of conceptual progress in science, stressing how the reference potential of 'planet' improved in the change from late Ptolemaic astronomy to Copernicus' one (see Kitcher 1995, p. 96, 105). According to Kitcher's reconstruction, in pre-Copernican astronomy some tokens of 'planet' referred to the planets kind, while other only to a certain subset of it (i.e., the wandering planets). Copernican astronomy conceptually improved this situation by disambiguating the reference potential of 'planet', in that it fixed the reference to the planets kind and it dropped the failed mode of reference to wanderers.

Our two examples from the formal sciences, i.e., the development of the ABSTRACT GROUP concept and the formalization of the notion of ALGORITHM, can also be read through the lenses of Kitcher's theory. In fact, Kitcher (1984) used already the notion of a reference potential to characterize the linguistic improvements of mathematical practices. According to Kitcher (1984, pp. 170-177), just like scientific practices, mathematical practices often involve heterogeneous ways of fixing the reference of some terms that are modified and improved in the course of scientific progress. Indeed, we can see the step from pre-abstract group theory to abstract group theory as constituting an improvement of the reference potential of 'group', in that the multiple vague and ambiguous ways of referring to a group used by different groups of mathematicians were replaced by a univocal, axiomatically specified way (cf. Feferman 1978; Wussing 1984). Analogously, the mathematical practice related to classical computability theory drastically improved with its formal definition of an algorithm the precedent pre-theoretical practice in mathematics of often referring to algorithms by giving certain paradigmatic examples of effective procedures (cf. Sieg 2009; De Benedetto 2021).

Things get more complicated for Kitcher's theory if we look at the case of IMPLICIT MEMORY. Here, the conceptual progressiveness seems to be not so much related to an improvement in the language of the relevant scientific community, but rather to the new experimental possibilities that the concept of implicit memory allowed (see Feest 2010). Nevertheless, an enthusiast of conceptual progress *qua* improvement in reference potential could argue that this episode of conceptual progress still involved an improvement in the reference potential of 'memory', in that the vastly heterogeneous reference potential of 'memory' got disambiguated by the introduction of 'implicit memory', which allowed the relevant psychological community to distinguish between explicit and implicit memory systems.

The problematic cases of conceptual progress for Kitcher's theory are the ones where the particular aims of a scientific community take central stage, as already argued in detail by Brigandt (2010) in his critique of Kitcher's theory. This difficulty of Kitcher's theory can be easily seen by looking at the case of the changes in the conceptualization of NATIONAL WELL-BEING. In this case, the conceptual improvement is solely understandable on the basis of the specific aim of the scientific community, namely, the search for a more inclusive view of the socio-economical well-being of a country. Without this specific aim in mind, the changes from the simple mono-dimensional concept of WELL-BEING, easily operationalizable via the GDP, to its convoluted multi-dimensional successors is not only not clearly conceptually progressive, but even conceptually regressive. Indeed, if we do not take into consideration the specific aims of the relevant scientific community and we just look at the changes in the reference potential of 'national well-being' (as Kitcher's theory prescribes), what we see is a conceptually regressive substitution of one univocal way of fixing the reference, with several different ways (some of which have also quite an ambiguous nature, cf. Costanza et al. 2009; Alexandrova 2017). This example demonstrates how Kitcher's theory, by equating conceptual progress with the approximation to an ideal language that tracks only natural kinds, cannot adequately treat historical episodes of conceptual progress where the goals of a scientific community take central stage.

We can summarize how well Kitcher's theory applies to our five examples of conceptual progress with the following table (Table 2):

| | Copernican | Memory | Well-Being | Group | Algorithm |
|---|---|---|---|---|---|
| Kitcher | ✓ | ≈ | × | ✓ | ✓ |

Table 2: The results of applying Kitcher's theory of conceptual progress to our five examples.

### 3.3 Brigandt's picture of conceptual progress

The third picture of conceptual progress we are going to focus on is Brigandt's (2010; 2012) epistemic-aim-centered view. I talk about a picture, rather than a theory like Laudan's or Kitcher's ones, for two reasons. First, Brigandt does not frame his ideas explicitly in terms of conceptual progress in science, but instead in terms of rational or warranted conceptual change. Secondly, Brigandt explicitly stresses that he does not want to propose a universal recipe for conceptual change, but a framework for understanding some episodes in the history of science. Thus, his picture is not so worked out and detailed as the other two we saw in this section. Nevertheless, a close look at Brigandt's picture will help us to understand some characteristics of (certain episodes of) conceptual progress inadequately described by Laudan's and Kitcher's theories.

Brigandt (2010) presents his views on conceptual change as a critical revision of Kitcher's views. He (2010, pp. 24-25) argues that Kitcher's reference-based view of conceptual progress cannot account for some important episodes of conceptual change in the history of science, due to its overly narrow focus on the extension and intension of scientific concepts. With a long case study on the evolution of the GENE concept in twentieth-century biology, Brigandt (2010, pp. 26-36) argues that in order to understand certain episodes of conceptual change, such as the case of GENE, we must look at the epistemic goals connected with scientific concepts.[9]

More specifically, Brigandt's (2010, pp. 21-25) view of conceptual change divides the semantic content of a scientific concept into three different components: the reference, the inferential role, and the epistemic goal. The first two

[9]Note that in this paper I use the terms 'aim' and 'goal' interchangeably.

components can be understood as the classical extensional (the reference) and intensional (the inferential role) semantic components of a concept, respectively playing a role analogous to Kitcher's reference and reference potential. The third component, i.e., the epistemic goal of a concept, is instead original to Brigandt's picture and it denotes the epistemic goal that the scientific community is supposed to pursue with the help of the concept. That is, the epistemic goal of a concept is the rationale for which a concept was introduced and maintained by a scientific community. This epistemic goal could consist of certain inferences that the concept is intended to support, an explanation that the concept is used for, or an experimental discovery that the concept figures in.

A conceptual change is progressive, according to Brigandt (2010, p. 24), if the new concept approximates the epistemic goal of a concept to a higher degree than its predecessor. Brigandt does not offer much more theoretical details, but he provides a detailed case study on the iterated conceptual progresses of the GENE concept in 20th-century biology (see Brigandt 2010, pp. 26-36), where he convincingly argues that the conceptually progressive character of this episode of conceptual change is given by this increase in the approximation towards the epistemic goal of the GENE concept for the biological community. In another paper, he (Brigandt, 2012) also applies his view to other two cases in biology, i.e., EVOLUTIONARY NOVELTY (Brigandt, 2012, pp. 79-84) and HOMOLOGY (Brigandt, 2012, pp. 84-89).

Let us look at whether Brigandt's epistemic aim picture makes sense of our five historical examples of conceptual progress. Brigandt's picture seems well-equipped to describe what happened in two cases of conceptual progress in our list, namely, the case of IMPLICIT MEMORY and the case of NATIONAL WELL-BEING. As we have stressed in our critical assessment of Laudan's and Kitcher's teories, in fact, the conceptual progressiveness of these two cases fundamentally revolves around the satisfaction of some specific aims of the relevant scientific communities. As such, Brigandt's picture can assess these two cases of conceptual change as cases of conceptual progress relative to two clear epistemic aims related to the concepts under focus, namely, the goal of conceptualizing experimental dissociations phenomena in order to formulate and test empirical hypotheses about them, in the IMPLICIT MEMORY case, and the search for a more complete and inclusive view of the socio-economical well-being of a country, in the case of NATIONAL WELL-BEING.

With a bit of a stretch, Brigandt's picture can also assess as episodes of conceptual progress the cases of the Copernican revolution and of the formalization of ALGORITHM. Although, in fact, these two cases of conceptual progress arguably involve the fulfillment of multiple epistemic goals, none of which can be exclusively tied to the concept under focus, the possibility of multiple epistemic goals is explicitly licensed by Brigandt (see Brigandt 2010, p. 23). In this way, we could see the Copernican conceptual system as approximating the predictive goals of determining the motion of planets and calculating beforehand their positions better than its Ptolemaic predecessor and the classical concept of ALGORITHM as approximating the many inferential and explanatory goals of the mathematical community of the time (e.g., the resolution of several open mathematical problems with an algorithmic character, the development of a rigorous metamathematics, etc.) to a higher degree than its informal predecessors.

The other case in our list, instead, i.e., the development of the ABSTRACT GROUP concept, clearly falls outside the scope of Brigandt's picture. In fact, this episode arguably does not involve the satisfaction of any specific epistemic goal of the community, but rather entirely revolves around the radical reformulation of the concept under focus as a byproduct of a general methodological change of the related discipline. More specifically, it is the increase in abstraction and formalization of ABSTRACT GROUP concept in comparison to its pre-formal predecessors that makes it an instance of conceptual progress. This improvement was not clearly tied to any specific (set of) epistemic goal(s), but it was the result of a major change in mathematical methodology at the end of the nineteenth-century. As such, this case, together with the last two we saw, shows how the goals of a scientific community, around which Brigandt's picture of conceptual progress is centered, take central stage in some episodes of conceptual progress, but not in all cases.

We can then schematically represent the applicability of Brigandt's theory to our five cases of conceptual progress with the help of the following table (Table 3):

| | Copernican | Memory | Well-Being | Group | Algorithm |
|---|---|---|---|---|---|
| Brigandt | ≈ | ✓ | ✓ | × | ≈ |

Table 3: The results of applying Brigandt's picture of conceptual progress to our five examples.

## 4 A Cognitive-Pragmatic Theory of Conceptual Progress

We saw three different theories about conceptual progress in science and we analyzed their strengths and weaknesses in assessing five episodes of conceptual progress from the history of science. Although all the three theories we saw could make good sense of some of these five episodes, none could adequately characterize all of them as conceptually progressive.

Conceptual progress seems to be a phenomenon that is too diverse to be captured by a single neat definition. But why should we try to capture conceptual progress with a single definition in the first place? In this section, I will argue that conceptual progress in science is best understood as a fundamentally bi-dimensional phenomenon. More specifically, I will present a novel cognitive-pragmatic account of conceptual progress in science that builds on recent cognitive science to conceptualize this phenomenon as involving two different evaluative dimensions: a cognitive one, which I will call cognitive enhancement, and a pragmatic one, which I will call pragmatic optimization. In the next subsection (4.1), I will present my proposal in full generality, while, in subsection 4.2, I will show how my theory can account for all historical episodes of conceptual progress described in Section 2.

## 4.1 Cognitive Enhancement and Pragmatic Optimization

Conceptual progress in science is, I contend, best explicated as a combination of progress in two different dimensions, i.e., cognitive enhancement and pragmatic optimization. Cognitive enhancement is the cognitive dimension of conceptual progress that tracks the degree to which scientific concepts are good cognitive tools. Pragmatic optimization is instead the pragmatic dimension of conceptual progress that tracks the degree to which scientific concepts help a given scientific community to achieve its specific goals.

Before presenting my theory and its two evaluative dimensions, let me first clarify a couple of potentially contentious points. First, the unit of analysis of my theory of conceptual progress will be a conceptual system, i.e., a group of interrelated concepts that represent entities of a given domain. Nothing hinges particularly on this choice, as the theory could be applied to any group of concepts and, in principle, also to single concepts. My preference for the unit of conceptual systems is just a pragmatic one, as I think that conceptual systems dovetail nicely, in size and nature, with scientific theories, which are the most common unit of analysis for cognitive progress in science. I will furthermore not make any epistemological or ontological assumptions on concepts, i.e., I will not assume any specific theory of conceptual structure (e.g., prototype, exemplar, atomistic, theory-theory, functional, etc.) nor any metaphysical stance about what kind of entities concepts are (e.g., psychological, linguistic, abstract, worldly, hybrid, etc.). I will just assume that our concepts talk is somehow connected with the abstract bodies of knowledge, stored in the long-term memory, with which we perform several higher-cognitive tasks such as categorization, abstraction, conceptual inferences, and the like.[10] Finally, I will not take a stance on the scientific realism vs anti-realism debate. My theory of conceptual progress will be equally acceptable by both camps, since it neither is an explicitly realist one (like Kitcher's) nor an explicitly anti-realist one (like Laudan's).

After these preliminary clarifications, let us look at the two dimensions of my theory, i.e., cognitive enhancement and pragmatic optimization, in some detail.

**Cognitive Enhancement** I call cognitive enhancement the dimension of conceptual progress that tracks how good scientific concepts are as cognitive tools. That is, this dimension tracks how much scientific concepts support the higher-cognitive activities for which we use concepts, i.e., inferences, categorization, abstraction, memory, learning, and the like. Concepts, in this dimension, are evaluated as cognitive tools for storing and producing information. All concepts allow us to store information in our long-term memory and to produce new information via categorization and conceptual inferences (cf. Margolis and Laurence

[10]In this way, enthusiasts of a psychological view of scientific concepts can just identify them with these mental bodies of knowledge, while supporters of a different ontological view of concepts can choose a looser connection between the two realms.

1999; Murphy 2002). Yet, as cognitive scientists have widely stressed, certain systems of concepts do that better than others (cf. Rosch and Mervis 1975; Heyes 2018; Douven and Gärdenfors 2019; Egré and O'Madagain 2019). Good concepts store information in a coherent way, they allow us fast categorization processes thanks to their optimal division in maximally-similar kinds, and they allow us to draw many inferences thanks to the richness of their conceptual structure. Bad concepts, instead, overlap with each other in a contrasting manner, they categorize entities in ways that are not very inferentially productive, they leave many borderline cases in the domain. Psychologists and philosophers have offered several measures of this cognitive "goodness" of conceptual systems (cf. Thagard 1992; Murphy 2002; Douven and Gärdenfors 2019; Egré and O'Madagain 2019). Without singling out any specific theory or measure of this cognitive goodness, the dimension of cognitive enhancement tracks this specific sense in which a conceptual system can be seen as better than another one. In this dimension, conceptual system are evaluated *qua* general ways of storing and producing knowledge about a domain. This evaluation takes into consideration just the cognitive properties of the conceptual system as a possible classification of the relevant domain of application, no weight is given to the specific intentions or goals of the relevant scientific community.

Although this way of evaluating concepts *qua* general tools has been more explicit in the psychological literature on concepts, several normative accounts of conceptual change seem to implicitly evaluate concepts in this specific cognitive sense (cf. Carnap 1950; Thagard 1992; Andersen, Barker, and Chen 2006; De Benedetto 2022). The emphasis that Carnap (1950), in his account of explication, puts on features of a conceptual systems such as accuracy, scope, and internal coherence, for instance, can be seen as an evaluation of cognitive enhancement, since these features are usually considered to be positively correlated with the general cognitive utility of a conceptual system. Similarly, the emphasis that several cognitive theories of conceptual change in science (e.g., Thagard 1992; Andersen, Barker, and Chen 2006) put on the discrimination power, generalization support, and the inferential fruitfulness of conceptual systems can be interpreted, in my proposal, as an evaluation pertaining to the dimension of cognitive enhancement. Indeed, seen at its limit, cognitive enhancement explicates progress towards one of the most common philosophical ideal that a conceptual system in science should strive for achieving, namely, an optimal categorization of phenomena in inferentially-rich kinds or, in other words, an ideal understanding and description of the world.

**Pragmatic Optimization** I call pragmatic optimization the dimension of conceptual progress that tracks how well scientific concepts support the achievement of the specific goals that a given scientific community sets itself. In contrast to the dimension of cognitive enhancement, in which concepts are evaluated solely on the basis of their cognitive usefulness as general cognitive tools, in this dimension, concepts are evaluated solely in terms of their pragmatic usefulness in helping the relevant scientific community to achieve its specific goals. These goals might be related to the improvement of any activity or component of the practice of a given scientific community. Examples include specific inferences that a concept must support, methodological procedures (experiments, evidence evaluation) in which the concept must figure, novel explanations of phenomena, and application of theories and models to different domains. Importantly, these goals are not meant to be purely epistemic in character, but they can also include pragmatic aims of the scientific community, such as familiarity of use of the concepts, models, and theories involved, questions about practical applicability, and the like. Improvements in pragmatic optimization are achieved when a conceptual system allows a scientific community to satisfy its epistemic and pragmatic goals to a higher degree than its predecessors. In this dimension, conceptual system are evaluated *qua* specific tools for the improvement of the scientific activities of a given community. The evaluation of a conceptual system in terms of pragmatic optimization takes into consideration just how good a conceptual system is for the specific aims of a given scientific community, without judging its general utility as a way of storing and producing knowledge. In this way, an evaluation of pragmatic optimization is meaningful only relative to a given set of aims of a given scientific community.

The idea of evaluating concepts in terms of their specific usefulness in achieving certain goals has been recently studied in both cognitive science and philosophy of science. In the last decades, in fact, cognitive scientists have stressed the significance of human goals in the construction and use of many everyday concepts (cf. Barsalou 1983, 1991; Markman and Stilwell 2001; Ratneshwar et al. 2001; Goldwater, Markman, and Stilwell 2011; Voorspoels, Storms, and Vanpaemel 2013; Heyes 2018). Empirical evidence indicates that epistemic and pragmatic goals related to practical planning importantly shape the conceptual system of a cognitive agent, making her construct concepts specifically tailored for a certain goal and modify many concepts she already possesses to perform better a given task (cf. Ratneshwar et al. 2001; Jee and Wiley 2007; Chin-Parker and Birdwhistell 2017; Chin-Parker, Brown, and Gerlach 2025). These task-dependent concepts are often called ad-hoc (Barsalou, 1983), goal-derived (Barsalou, 1991; Ratneshwar et al., 2001; De Benedetto, 2024), or role-governed (Markman and Stilwell, 2001) concepts and they possess particular properties related to their purely functional role in our cognition that distinguish them from other types of concepts.[11]

Philosophers of science have also recently highlighted how important are epistemic and pragmatic goals of the relevant scientific community for understanding the construction and change of scientific concepts (cf. Wilson 2006; Nersessian 2008; Brigandt 2012; Neto 2020; Novick 2023; Taylor 2023; Haueis

[11]Traditional examples of goal-derived concepts are THINGS TO TAKE ON VACATION and CLOTHES FOR THE WINTER. In particular, goal-derived concepts do not typically score very high on general cognitive utility, as they typically divide the domain in kinds that do not have a high within-category similarity and that do not support many inferences (cf. Barsalou, 1983; Chin-Parker and Birdwhistell, 2017). Yet, goal-directed concepts are typically excellent in supporting agents to achieve the specific goals for which they were constructed (cf. Barsalou 1991; Ratneshwar et al. 2001).

2024; De Benedetto 2024), as well as the more general epistemic dynamics of a community of scientists (cf. Dupré 1993; Mitchell 2009; Elliott and McKaughan 2014; Potochnik 2017). Arguably, many fundamental epistemic activities of a given scientific community, such as theory choice, model building, and evidence gathering, are affected (and even sometimes guided) by specific epistemic and pragmatic goals of the community. Indeed, as we saw in the last section, some episodes of conceptual change from the history of science can be understood as conceptually progressive only by considering the specific goals of the relevant scientific community. The dimension of pragmatic optimization encapsulates the centrality of epistemic and pragmatic community aims for (certain episodes of) scientific conceptual change as one of the two evaluative dimensions of conceptual progress. Pragmatic optimization explicates progress towards this context-dependent ideal of scientific inquiry, namely, an optimal support for the achievement of the aims of a given scientific community.

Conceptual progress in science is best understood, I contend, as a combination of these two dimensions, namely, cognitive enhancement and pragmatic optimization. That is, conceptual progress is a cognitive-pragmatic notion that involves a normative evaluation of two different dimensions, one dimension evaluating the general cognitive usefulness of a conceptual system and one dimension evaluating the increase in the optimization of a conceptual system with respect to the specific goals of the relevant scientific community. A given episode of scientific conceptual change constitutes then conceptual progress if it involves an increase in cognitive enhancement or in pragmatic optimization (or, both, as it is often the case).

It is important to stress that the two dimensions of conceptual progress that I distinguished, namely, cognitive enhancement and pragmatic optimization, might come together, both in practice and in theory. That is to say that, often, paradigmatic episodes of conceptual progress in science involve simultaneously an increase in cognitive enhancement and in pragmatic optimization. Also, theoretically, we should expect an increase in one dimension to often cause an increase in the other dimension. This should not come as a surprise, as the two dimensions can be seen as tracking improvements in, respectively, general cognitive utility and pragmatic usefulness for specific goals. From a cognitive perspective, psychologists have repeatedly stressed how higher-cognitive abilities like categorization and inferences are deeply intertwined with goal-directed activities like planning and acting (cf. Murphy 2002; Barsalou 2003; Jee and Wiley 2007; Chin-Parker, Brown, and Gerlach 2025), so that having better cognitive tools can be expected to increase our ability of reaching our goals. Even in science, it seems natural to think that having better cognitive tools would make the achievement of the goals of a given scientific community easier, and conversely, that the achievement of many goals of scientific inquiry requires a general cognitive improvement of our concepts. Indeed, we have encountered this interrelationship between cognitive enhancement and pragmatic optimization in some historical examples we saw in the last section. Take, for instance, the case of the formalization of our intuitive concept of ALGORITHM. In this case, we recalled how several specific goals of the mathematical community of the time (e.g., solving the *Entscheidungsproblem*, generalizing Gödel's incompleteness results, etc.) presupposed a formal concept of ALGORITHM that could be quantified over. That is, in my terminology, this was a case in which pragmatic optimization (i.e., the usefulness of a concept for achieving certain goals of the community) required a distinctive type of cognitive enhancement (namely, a fully formalized concept with a sharply defined scope). Conversely, in other episodes, it is a specific kind of cognitive enhancement that can produce, as a byproduct, some form of pragmatic optimization. For instance, in the Copernican revolution, one could observe how the increase in simplicity and internal consistency of the Copernican conceptual system (cognitive enhancement) allowed the scientific community to better determine the motion of planets and thereby to solve the pressing problem of the calendar (pragmatic optimization).

Nevertheless, my contention is that these two dimensions of conceptual progress are conceptually distinct and must therefore be kept apart in a normative theory of conceptual progress. We saw in fact how different are the evaluative assessments involved in the two dimensions. In judging cognitive enhancement, what matters are the cognitive features of a conceptual system (e.g, how efficiently it clusters the entities in the intended domain, etc.); in judging pragmatic optimization, what matters is just the relationship between a conceptual system and the goals of the relevant scientific community (i.e., how useful is a conceptual system for achieving a given set of goals). Importantly, the evaluation of pragmatic optimization is contextually dependent on the relevant scientific community (and on its goals), whereas the evaluation of cognitive enhancement remains the same from a community to another. This is because the latter dimension judges concepts *qua* general ways of storing and producing knowledge about a given domain, and not as specific tools for certain actions or goals of a community (as instead the former dimension does). Moreover, the two dimensions track progress towards two different ultimate ideals: on the one hand, as the ultimate limit of cognitive enhancement, we could envision a perfect taxonomy of the world; on the other hand, as the ultimate limit of pragmatic optimization, we could envision a perfect support for the specific inquiries of a given scientific community. These two ideals represent two different, partial views of what concepts are good for. As the cognitive scientist Lawrence Barsalou writes:

> "At the one extreme, people are intuitive taxonomists. Their goal is to discover the categorical structure of the world, develop taxonomic systems that represent this structure, and establish background theories that frame these taxonomies. At the other extreme, people are goal achievers who organise knowledge to support situated action. On this view, the primary organisation of the conceptual system supports executing actions effectively in the environment, with taxonomic hierarchies constituting a secondary-level of organisation that supports this activity" (Barsalou, 2003, p. 546)

On top of these theoretical reasons for separating the dimension of cognitive enhancement from the dimension of pragmatic optimization in a theory of conceptual progress, there is also an empirical-historical case to be made for this distinction. Indeed, we already saw that these two dimensions can come apart, in both everyday situations and scientific contexts. In everyday situations, concepts scoring not so high on general cognitive utility might be excellent in helping agents to achieve their specific goals, as highlighted by the aforementioned empirical studies of goal-derived concepts. More importantly for our present topic, we already saw that there are some cases in the history of science in which these two dimensions arguably come apart, as we analyzed certain episodes of conceptual progress that arguably constitute progress with respect to only one of these dimensions. This is what we witnessed in the case of the change in NATIONAL WELL-BEING, where the pragmatic optimization involved in the step from a mono-dimensional to a multi-dimensional concept did not determine a cognitive enhancement. Conversely, the case of the ABSTRACT GROUP concept can be seen as an instance of cognitive enhancement that was not coupled with any pragmatic optimization.

For all these reasons, I claim that cognitive enhancement and pragmatic optimization should be conceived as separate evaluative dimensions in a theory of conceptual progress. Conceptual progress is best understood as a fundamentally bidimensional phenomenon, as a progress towards not one single ideal, but instead towards two distinct ideals, i.e., a perfect taxonomy and a perfect support for goal-achievement.

## 4.2 Five cases of conceptual progress

In order to substantiate my argument for the cognitive-pragmatic theory of conceptual progress I just presented, let us see how it can make sense of all the five cases of conceptual progress that accompanied us throughout this paper.

**Copernican Revolution.** The Copernican revolution clearly classifies as clear-cut case of conceptual progress for my theory due to the remarkable improvement in cognitive enhancement, together with the significant pragmatic optimization, determined by the change from late Ptolemaic astronomy to Copernicus' theory. In fact, this conceptual change drastically increased the internal consistency and the simplicity of the relevant conceptual system, eliminating mildly inconsistent and heterogeneous categories, such as wanderers and epycicles (and the whole zoo of equants and eccentrics that the late Ptolemaic astronomy needed to keep up with the anomalies), and replacing them with a clear-cut homogeneous new definition of planet and a simple set of auxiliary concepts. The new conceptual system of Copernicus' theory is thus arguably a better cognitive tool than its predecessors, allowing richer inferences and a better, simpler way of storing information in clear kinds. This episode of conceptual change involves also a significant pragmatic optimization in that it helped the astronomical community of the time to achieve better the important epistemic goal of determining the motion of the planets, thereby also allowing them to achieve the important pragmatic goal of solving the pressing problem of the calendar. In this way, according to my theory, the Copernican revolution represents a clear case of conceptual progress, underlying a major improvement in the dimension of cognitive enhancement and also a significant improvement in the dimension of pragmatic optimization.

**Implicit Memory.** The development of the concept of IMPLICIT MEMORY qualifies also as a case of conceptual progress, due to the significant improvement in pragmatic optimization that its introduction determined. This concept allowed, in fact, psychologists to formulate more fine-grained testable hypotheses and to elaborate important exploratory experiments in dissociation phenomena (cf. Graf and Schacter 1985; Schacter 1987; Feest 2010). Although the introduction of IMPLICIT MEMORY does not seem to constitute such a significant improvement in cognitive enhancement, this episode can still be seen as involving a minor improvement in this dimension of conceptual progress, in that it helped to disambiguate the scope of MEMORY concepts in twentieth-century psychology. As such, according to the cognitive-pragmatic theory of conceptual progress, the introduction of IMPLICIT MEMORY in twentieth-century psychology clearly classifies as a case of conceptual progress, underlying a major improvement in the dimension of pragmatic optimization and a minor improvement in the dimension of cognitive enhancement.

**National Well-Being.** The recent change in the conceptualization of NATIONAL WELL-BEING in economics clearly classifies as a conceptual progress according to my theory, due to the remarkable improvements in pragmatic optimization that this conceptual change determined. The change from the simple, mono-dimensional concept of NATIONAL WELL-BEING, understood as pure economic growth and operationalized via the GDP, to the multi-dimensional concept employed nowadays in well-being science, understood as the growth of natural, physical, social, and human capital and partly operationalizable via indicators such as the GPI and the HDI, equipped economists with a quantifiable notion of WELL-BEING that takes into account several non-economical dimensions highlighted by psychologists and sociologists (Daly and Cobb, 1989; Stiglitz, Sen, and Fitoussi, 2010). Moreover, the multi-dimensional concept of NATIONAL WELL-BEING allowed an explanation of some important inequalities in the reported quality of life of developed and under-developed countries alike (Costanza et al., 2009; Kubiszewski et al., 2013). Because of this remarkable improvement in pragmatic optimization, this is indeed a case of conceptual progress. It is also a case of pure pragmatic optimization, where the improvement in this evaluative dimension is not coupled with an improvement of cognitive enhancement. This is why the conceptual progressiveness of this episode was not adequately assessed by Kitcher's theory, which focused only on (certain features naturally related to) the cognitive enhancement dimension.

**Abstract group concept.** The development of the ABSTRACT GROUP concept also qualifies as a case of conceptual progress for my theory, albeit for very different reasons than our last example. This episode is, in fact, arguably a case of pure cognitive enhancement, i.e., it involves improvement in the cognitive dimension of conceptual progress not coupled with any significant pragmatic optimization. The step from the pre-abstract GROUP concepts to the ABSTRACT GROUP concept drastically improved the cognitive usefulness of the GROUP concept, expanding the intended scope of the concept, unifying many different results and theorems on groups, rigorizing the definition of a group via the group axioms, and improving the methodology used by mathematicians working in these areas (cf. Wussing 1984; De Benedetto 2023). These clear improvements in cognitive enhancement determined by the development of the abstract group concept were not arguably related to any specific epistemic goal of the relevant mathematical community of the time. This is why it seemed unclear, to the very least, how to apply Brigandt's aim-centered picture of conceptual progress to this episode of conceptual change.

**Classical Algorithm.** Finally, the formalization of the notion of ALGORITHM clearly qualifies as an episode of conceptual progress according to the cognitive-pragmatic theory, remarkably involving a major improvement in both evaluative dimensions. The multiple definitions of algorithm developed in 1936, in fact, determined an extreme improvement in cognitive enhancement, due to their formality, rigor, and generality (cf. Sieg 2002; De Benedetto 2021). At the same time, the classical concept of ALGORITHM also allowed the newborn community of computability theorists to achieve many of their most important goals, such as solving two different problems of Hilbert's century list, having a measure of what is computable and what is not, and achieving a robust mathematization of the ubiquitous notion of effective procedure (cf. Gandy 1988; Sieg 2009). All these achievements determined by the classical notion of ALGORITHM make it also a paradigmatic case of pragmatic optimization. By constituting a remarkable improvement in both evaluative dimensions of conceptual progressiveness, the formalization of the notion of ALGORITHM represents a paradigmatic case of conceptual progress in science.

We have seen how the cognitive-pragmatic theory of conceptual progress manages to adequately characterize all these episodes of conceptual change as constituting conceptual progress. It manages to do that thanks to its bi-dimensional character, i.e., by conceptualizing conceptual progress as a phenomenon involving two different evaluative dimensions, a cognitive and a pragmatic one. Episodes of conceptual progress from the history of science can then improve only one of these dimensions or, as it is often the case, involve improvements in both dimensions. We can then think about episodes of conceptual progress as points in a two-dimensional space of conceptual progress (Figure 1):

To conclude the presentation of my cognitive-pragmatical theory of conceptual progress, let me clarify a couple of other aspects of it.[12] The first one concerns how my theory can deal with negative examples of conceptual progress. In presenting my theory, I only focused on positive examples of progress (taken

[12] I owe to two anonymous reviewers the idea of clarifying these two aspects of my theory.

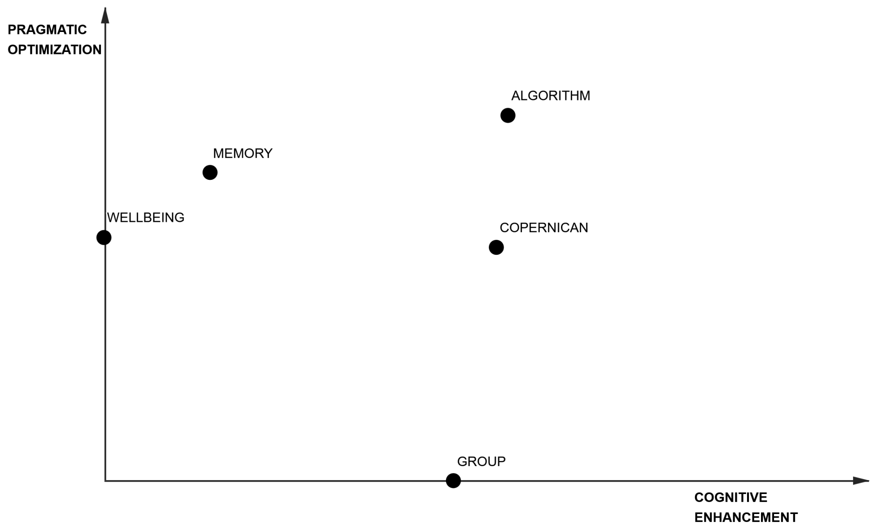


Figure 1: A graphic depiction of how the cognitive-pragmatic theory of conceptual progress is able to assess, in two dimensions, the progressiveness of the five historical cases. The X-axis represents the dimension of cognitive enhancement, while the Y-axis represent the dimension of pragmatic optimization.

from the list of historical episodes of conceptual progress in Section 2). This does not mean that any conceptual change whatsoever is deemed progressive by my theory nor that the history of science depicts an everlasting series of conceptual progresses. Indeed, as many analyses of failing research programs and paradigm crises show (e.g., Kuhn 1970; Laudan 1978, 1984; Thagard 1992; Andersen, Barker, and Chen 2006), one can find in the history of any science episodes of conceptual change that involve the introduction of foreign auxiliary concepts into a conceptual system, an introduction that can be sometimes forced by empirical needs or by reason of external coherence between different models and theories.[13] Such ad-hoc introductions of concepts would naturally be deemed not conceptually progressive by my theory, as they arguably do not involve any cognitive enhancement nor any actual satisfaction of the scientific goals of the relevant community. A second aspect of my theory that I did not mention in the foregoing discussion is the possibility of trade-offs between its two evaluative dimensions. We saw, in fact, that cognitive enhancement and pragmatic optimization might come apart, in the sense that there are cases of conceptual progress that involve an improvement in only one of the two evaluative dimensions recognized by my theory. Thus, the two dimensions can pull in different directions. Can they pull in opposite directions? And, if so, under

[13]Traditional examples of such ad-hoc conceptually regressive introductions are, for instance, the introduction of epycicles in the orbits of geocentric conceptual systems and the redefinition of phlogiston as having negative mass.

which conditions such a trade-off between these two dimensions constitutes a conceptual progress? I am tempted to answer negatively to the first question, as it is not easy for me to imagine a scientific goal, the achievement of which is negatively correlated with the cognitive enhancement of the relevant conceptual system.[14] Perhaps such a trade-off could be realized by a scientific community starting to work with a very restrictive new methodology, a methodology that forbids many possibly good ways of categorizing the world. A conceptual change prompted by such a restrictive methodology would perhaps be a case where an increase in pragmatic optimization would determine a decrease of cognitive enhancement. In such a case, perhaps the increase in one dimension should be weighted against the decrease in the other in order to judge whether the whole change is a conceptual progress or not.[15]

# 5 Conclusion

Let me recap the main steps of the present work. We started with focusing on five historical cases of conceptual progress, taken from different sciences and different centuries. We then assessed these case studies through the lenses of three influential theories of conceptual progress and we saw how none of the theories manages to adequately account for the diversity of conceptual progresses that these historical episodes exhibit. In order to adequately characterize this diversity, I proposed to conceptualize conceptual progress in science as a fundamentally bi-dimensional phenomenon. More specifically, building upon recent cognitive science, I presented a cognitive-pragmatic theory of conceptual progress that understands this phenomenon as involving two different evaluative dimensions: cognitive enhancement and pragmatic optimization. I then showed how this cognitive-pragmatic theory is able to adequately characterize all five historical episodes as conceptually progressive thanks to its two evaluative dimensions.

The cognitive-pragmatic theory of conceptual progress constitutes an important step forward in our understanding of conceptual progress in science, in that it shows the inherent bidimensionality of this normative phenomenon. When scientists and philosophers assess a given episode of conceptual change as conceptually progressive, they make a complex normative judgment. This judgment involves considering both the general goodness of a group of scientific concepts as a general cognitive tool and their usefulness for achieving the specific goals of the relevant scientific community. In this way, we can see how the present cognitive-pragmatic theory of conceptual progress, in contrast with the traditional mono-dimensional theories of conceptual progress, does not depict

[14] This point underlies a significant difference between the dynamics of scientific concepts and everyday conceptual change. As I mentioned before, in everyday life, we often construct on-the-fly concepts that have very low general cognitive utility for achieving very specific goals.

[15] This could be done by adding some way of measuring the extent of the increase/decrease in the two dimensions, in a way analogous to how Laudan imposes weights on the significance of conceptual and empirical problems (see Laudan, 1978, pp. 64-68).

a single ideal of conceptual progressiveness that scientific concepts should approximate, but understands instead conceptual progress as approximating two different ideals: a perfect taxonomy of the world and an optimal support for human action.

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