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The Functional Approach: Scientific Progress as Increased Usefulness

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[E]very new discovery has led to new problems and new methods of solution, and opened up new fields for exploration. (Bury 1920, 3)

When talking of the functional approach, one tends to think of Thomas Kuhn's or Larry Laudan's account of scientific progress. Both emphasise the significance of problem-solving in science. For Kuhn (1970b) and Laudan (1977; 1981), science progresses if more problems are solved or problems are solved in a more effective and efficient way. This is probably why the functional approach is also sometimes called the problem-solving approach.

> The principal proponents of the problem-solving approach to progress are Thomas Kuhn (1970) and Larry Laudan (1977). (Bird 2016, 546)

> There are other approaches to scientific progress in the literature. They are the semantic approach (Niiniluoto 1980, 2014) and the problem-solving approach (Kuhn and Thomas 1962/1970; Laudan 1977, 1984). (Park 2017, 570)

> Kuhn's idea is fleshed out by Larry Laudan in his problem-solving account of scientific progress. (Dellsén 2018, 2)

Accordingly, the key feature of the functional approach has often been summarised as problem-solving.

> The principal representatives of [the functional approach] are the puzzle- and problem-solving views of Kuhn and Laudan… This view is functional because it takes progress to be a matter of the success a scientific field has in fulfilling a function—that of solving problems. (Bird 2007, 67)

> Each account places its own distinctive type of cognitive achievement at the heart of scientific progress—truthlikeness, problem-solving, knowledge, or understanding. (Dellsén 2018, 2)

Unfortunately, this is highly problematic to identify the functional approach with the problem-solving approach. It might be true that Kuhn's and Laudan's approaches are better known than other functional approaches, but it is incorrect to claim that the functional approach is just the problem-solving approach. Other representatives include the Popper-Lakatos functional approach (Popper 1963; Lakatos 1978) and my new functional approach (Shan 2019; 2020a). There is a danger of conflating the functional approach with the problem-solving approach: it seems to many that the functional approach is simply indefensible as both Kuhn's and Laudan's problem-solving approaches face serious challenges. In this chapter, I defend the functional approach to scientific progress. In section 2, I critically examine two traditional versions of the functional approach. In section 3, I elaborate my new functional approach. In section 4, I argue that my new functional approach is better than the epistemic, semantic, and noetic approaches. In section 5, I address two objections to my approach.

1. Traditional Functional Approaches

The most influential representative of the functional approach is first proposed by Kuhn (1962; 1970a) and further developed by Laudan (1977; 1981). Kuhn (1970b, 164) argues that the nature of scientific progress is the increase of 'both the effectiveness and the efficiency with the group as a whole solves new problems'. Laudan (1981, 145) is also explicit on the point that 'science progresses just in case successive theories solve more problems than their predecessors'. Kuhn and Laudan differ in the explication of problem-solving, though. For Kuhn (1970b, 189–91), a problem *P* is solved if its solution is sufficiently similar to a relevant paradigmatic problem-solution. For Laudan (1977, 22–23), a problem *P* is solved by a theory *T* if *T* entails an approximate statement of *P*. Nevertheless, both Kuhn and Laudan maintain that scientific progress is nothing to do with truth or knowledge if truth or knowledge is construed in a classical way. More specifically, whether a problem is solved is independent of whether the paradigmatic solution assumes any paradigm-dependent truth (for Kuhn), or whether the background theory is true (for Laudan). Since the acceptance of a problem solution is determined independently of external factors like truth or knowledge, whether a progress is achieved can be judged by the scientific community itself . Thus, as I have summarised in some earlier work (Shan 2019; 2020a), there are four central tenets of the Kuhn-Laudan functional approach to scientific progress.[1]

> T1. Scientific progress is solely determined by the problem-solving power.
>
> T2. The problem-solving power is assessed by the amount and significance of the problems solved.
>
> T3. The problem-solving power is independent of whether the solution is true or knowledge.
>
> T4. Scientific progress is judged and known by the scientific community.

The Kuhn-Laudan approach has weathered a great deal of criticisms. As I have summarised in Shan (2019; 2020a), there are four main objections, which correspond to the four central tenets respectively. T1 faces the problem of sufficiency: an accumulation of problem-solutions does not guarantee progress in science. As Alexander Bird (2007, 69–70) argues, it seems implausible for many to accept that there is an ongoing progress in science, as the false solution statements (derived from the false theory) accumulate. T2 encounters the problem of quantitative weighing: it is difficult to find a proper quantitative way to identify and calculate the problems of different significance. T3 is challenged by the problem of counter-intuition: it seems counter-intuitive to many that scientific progress is conceptually independent of truth or knowledge. T4 is susceptible to the problem of internalism: the Kuhn-Laudan approach implies that a scientific community well recognises whether it is making progress or not by examining its problem-solving power, but this is difficult to hold from a historical point of view. It is not unusual for a scientific community to overlook the significance of some scientific work.[2] These problems are so serious that it seems to be a difficult task for one to defend the Kuhn-Laudan approach. To some extent, it is no wonder the Kuhn-Laudan approach has been taken for granted indefensible.

However, as I have emphasised, the Kuhn-Laudan approach should not be conflated with the functional approach. Therefore, the functional approach should not be simply rejected or neglected just because there are many problems of the Kuhn-Laudan approach.

Another representative of the functional approach is rooted in the work of Karl Popper (1959; 1963) and mainly developed by Imre Lakatos.[3] For Popper (1963, 217), the criterion of scientific progress is testability: a scientific theory is progressive if it 'contains the greater amount of empirical information or content', 'has greater explanatory and predictive power', and 'can therefore be more severely tested by comparing predicted facts with observations'. Popper's criterion consists of two requirements.

> Logical requirement: a progressive theory should have more falsifiable content.
> Empirical requirement: a progressive theory should pass new and severe tests.

Following Popper's idea, Lakatos (1978, 33–34) develops his functional account of scientific progress: a research programme is progressive if it generates novel and well corroborated predictions. Inspired by Popper's two requirements, Lakatos carefully distinguishes two types of progress in science: theoretical progress and empirical progress. If a research programme is merely generating uncorroborated novel predictions, it only counts as theoretical progress. Only when novel predications are corroborated by experiments, a research programme is making empirical progress. The real sense of scientific progress, for Lakatos, consists of both theoretical progress and empirical progress.

> That is, I give for criteria of progress and stagnation within a programme and also rules for 'elimination' of whole research programmes. A research programme is said to be progressing as long as its theoretical growth anticipates its empirical growth, that is, as long as it keeps predicting novel facts with some success. (Lakatos 1978, 112)

It is evident that there is a crucial difference between the Popper-Lakatos and Kuhn-Laudan approaches. They differ in the key function of science. For Kuhn (and Laudan to a less extent), science is basically about problem-solving. In contrast, Popper and Lakatos maintain that falsifiability is the key virtue of science and highlight the significance of novel predictability.[4] Such a difference makes the Popper-Lakatos approach less vulnerable to some challenges that the Kuhn-Laudan approach faces. It is clear that the problem of quantitative weighing is inapplicable, as the Popper-Lakatos approach does not define scientific progress in terms of problem-solving. Neither is there a problem of counter-intuition for the Popper-Lakatos approach. Novel predictability is arguably related to verisimilitude or truthlikeness. It is not very clear if the Popper-Lakatos approach suffers a problem of sufficiency. At least, it is not simply undermined by Bird's thought experiment (2007, 69–70).

That said, the Popper-Lakatos approach does face the problem of internalism, like the Kuhn-Laudan approach. Whether a research programme generates novel and corroborated predictions can be easily judged by a scientific community. In other words, the Popper-Lakatos approach is as internalist as the Kuhn-Laudan approach is.[5] But it would be too hasty for one to conclude that the functional approach is seriously challenged by the problem of internalism. In the next section, I shall introduce a non-internalist functional approach.

2. The New Functional Approach

Recently, I have developed a new functional approach (Shan 2019; 2020a). In a nutshell, I define scientific progress as follows:

> *Science progresses if and only if more useful exemplary practices are proposed.*

This approach shares two basic assumptions behind the functional approach.

> A1. Scientific progress should be analysed and assessed in a holistic way.
>
> A2. Scientific progress is determined by the fulfilment of key functions of science.

Both the Kuhn-Laudan and Popper-Lakatos approaches assume that the nature of scientific progress is about how a scientific community fulfils the key functions of science. They both maintain that the unit of analysis for examining scientific progress should be a community-based consensus, though they differ in how to characterise it. The unit of analysis in the Kuhn-Laudan approach is a paradigm or a research tradition, while the unit of analysis in the Popper-Lakatos approach is a research programme. Thus, scientific progress cannot be applied to characterise some improvement of or advance in particular scientific activities. For example, it makes little sense to say that Galileo's improvement of telescope was progressive. In contrast, it only makes sense to argue that Galileo's improvement of telescope contributed to a progressive paradigm or research programme. I am sympathetic to this view that scientific progress should be analysed and assessed in a holistic rather than a piecemeal way.

However, my new functional approach differs from two traditional functional approaches in two main aspects: the unit of analysis and the key virtue of science. The unit of analysis in the new functional approach is an exemplary practice, which is defined as a particular way of problem-defining and problem-solving, typically by means of problem-refining, conceptualisation, hypothesisation, experimentation, and reasoning (Shan 2020b). It should be highlighted that an exemplary practice is different from a paradigm, a research tradition, and a research programme. The former is an example of the unit of micro-scientific consensus, while the latter are cases of the unit of macro-scientific consensus.[6] A marco-scientific consensus is something general or universal, invariantly shared by the members of a scientific community, such as theories, laws, and models. For example, for Kuhn, the paradigm of Newtonian mechanics consists of universal generalisations like F = ma, while for Lakatos, the research programme of Newtonian mechanics includes Newton's three laws of motion and the law of gravitation as the hard core. In contrast, a unit of micro-scientific consensus is something local and context-dependent. Mendel's work on the development of pea hybrids is such a case. It was accepted by early Mendelians in the 1900s. It is worth noting that what was accepted is (at least some components of) Mendel's particular way of problem-defining and problem-solving rather than the generality of Mendel's laws of development. Such a difference suggests an advantage of the new functional approach: it better captures the actual cases in history. It is often difficult to identify the content of a macro-scientific consensus. For example, it is natural to identify the theory of evolution by natural selection as the hard core of the Darwinian research programme, but it is extremely difficult to articulate what the theory of evolution by natural selection is. In particular, it is not an easy task to characterise an account of that theory which was invariantly shared by the members of the research programme. This is a problem for the traditional functional approaches which analyse scientific progress in terms of macro-scientific consensus. But it is not a problem for the new functional approach. As I have shown in Mendel's case, it is not very difficult to identify the micro-consensus among the members of a community. Early Mendelians did differ in the formulation of the Mendelian laws, but they all accepted Mendel's exemplary practice, which provides conceptual tools, experimental guidelines, problems, etc for the study of heredity.

The other important difference is that I argue that the key virtue of science is not problem-solving success or predictive novelty, but usefulness. The definition of usefulness is as follows.

> *An exemplary practice is useful if and only if the way of defining and solving the research problems is repeatable and provides a reliable framework for further investigation to solve problems and to generate novel research problems across different areas (or disciplines).*

The notion of usefulness encompasses four virtues: repeatability, problem-defining novelty, problem-solving promise, and interdisciplinarity. The repeatability of the way of defining and solving research problems is a prerequisite for the recognition of its usefulness. Consider the case of the Mendelian-Biometrician controversy in the history of genetics.[7] One main reason for W. F. R. Weldon (1902a; 1902b) to resist the Mendelian approach to the study of heredity was that he failed to repeat Mendel's conceptualisation of dominance and recessivenss, i.e. his way of distinguishing the dominant and recessive characters (in Weldon's word 'the ambiguity of Mendel's categories'). In contrast, Carl Correns' acceptance of (the usefulness of) the Mendelian approach (1900) was based on his successful repetition of Mendel's practice, including problem-defining, conceptualisation, hypothesisation, and experimentation. Moreover, the mixed reception of the Mendelian approach in the first decade of the 20th century was also due to the different results of the application of the Mendelian approach to studying the transmission of characters in other species. Hugo de Vries' acceptance of the Mendelian approach (1900a; 1900b) was because that it was successfully applicable to study the transmission of the morphological traits in various plant species (e.g. *Lychnis*, *Papaver*, and *Solanum*), while the scepticism arose from the unfavourable results of the application (e.g. Whitman 1904; McCracken 1905; 1906; 1907; Reid 1905; Prout 1907; Saunders 1907; Hart 1909; Holmes and Loomis 1909). Problem-solving promise has been widely acknowledged as a virtue of scientific practice (e.g. Kuhn 1970b; Laudan 1977; Nersessian 2008), while problem-defining novelty is also recently highlighted (Shan 2020b; 2020a). In addition, interdisciplinarity is another important virtue in scientific practice. Science advances with so many interactions of different disciplines, for example, astrophysics, biochemistry, and bioinformatics.[8] The interdisciplinarity of an exemplary practice helps to widen the scope and explore the novel lines of scientific inquiry. Gregor Mendel's work on pea hybrid development (1866) is a good example of an useful exemplary practice. As I have shown in greater detail (Shan 2020a), Mendel's exemplary practice introduced in his study of pea hybrid development was useful in the sense that it was repeatable in practice and provided the foundation for the 20th century study of heredity to solve the problems of transmission of the morphological traits of other species and to generate more potential testable research problems across the areas like cytology, evolution, and heredity.

In addition, it should be noted that usefulness is community-dependent. A particular exemplary practice might be taken as useful by some scientific communities but not others. The Mendelian-Biometrician controversy in the first decade of the 20th century well illustrates this point. The Mendelians, led by William Bateson, were optimistic on the future of the Mendelian approach to the study of heredity, while sceptics, including Weldon and Karl Pearson, doubted the usefulness of Mendel's approach (especially the conceptualisation, hypothesisation, and experimentation) to study the phenomena of heredity. In other words, Weldon and Pearson overlooked the 'progressive' element of the Mendelian approach due to their failure of the recognition of its usefulness. Thus, the usefulness of a given exemplary practice is not obvious to a scientific community. The progress thus achieved is not judged or known by the community. It is in this sense that my approach is not internalist.

I contend that this new functional approach well resolves the four main problems of the Kuhn-Laudan functional approach. Firstly, I have argued that whether science progresses depends on whether a new exemplary practice is more useful than the old one. In order to determine whether there is progress in science, one has to examine whether a new exemplary practice provides a more reliable framework to solve unsolved problems, and whether it proposes more novel and testable problems across more areas. Given such a qualitative notion of usefulness, there is no need to look for a quantitative framework to calculate and weigh the significance and amount of the problems. Thus, the problem of quantitative weighing is inapplicable to my functional approach. Secondly, my functional approach is not internalist. Bird construes the Kuhn-Laudan appraoch as internalist in the sense that scientific progress is only judged and known by a community, independent of any features unknown to them. However, this does not apply to my approach. The usefulness of an exemplary practice is not straightforwardly recognisable by the scientific community, as I just illustrated in the Mendelian-Biometrician controversy. Thirdly, I contend that by highlighting the significance of problem-defining, the problem of sufficiency is resolved. Fourthly, the problem of intuition can also be solved. As I mentioned, the functional approach is somehow neglected in the recent debate for its conflict with the intuition that scientific progress is about knowledge and/or truth. However, I argue that my functional approach can be compatible with this intuition. Usefulness of an exemplary practice could be *somehow* interpreted in terms of knowledge if knowledge is not merely construed as something propositional or theoretical. Knowledge is traditionally classified into know-that and know-how.[9] A particular way of problem-defining and problem-solving can be argued as a case of know-how. Thus, that more useful exemplary practices are proposed could be understood in the sense that more useful know-how is obtained. Moreover, usefulness of exemplary practices can be understood in terms of truth *to some extent*. In particular, it is well explained by the 'contextualist' theory of truth (Chang 2012; Massimi 2018). Michela Massimi (2018), for example, proposes that truth in the context of scientific practice should be defined in a perspectival way.

> Knowledge claims in science are [perspective-dependent] when their *truth-conditions* (understood as rules for determining truth-values based on features of the context of use) depend on the scientific perspective in which such claims are made. Yet such knowledge claims must also be assessable from the point of view of other (subsequent or rival) scientific perspectives. (Massimi 2018, 354)

If truth is defined in this perspectival way, then the increase of the usefulness of an exemplar practice implies a reliable framework with more novel problems and more confirmable hypotheses. The Mendelian approach to the study of heredity, for example, generated more confirmable hypotheses (e.g. the law of segregation) and factual knowledge (e.g. the summary of the transmission of morphological traits of various plants). All these hypotheses and factual knowledge are 'true' according to its perspective (i.e. the Mendelian approach) by means of experiments, while they are also assessable from the point of view of the subsequent scientific perspective (e.g. the Morgan approach) by new ways of experimentation. Therefore, more useful exemplary practices are proposed could be interpreted as more perspective-dependent true knowledge claims are attained.[10]

To sum up, I argue that new functional approach is better than both the Kuhn-Laudan and Popper-Lakatos functional approaches to respond the four main objections.

3. Transcending Knowledge, Truth, and Understanding

In this section, I argue that my new functional approach is better than its rival approaches. There are three other main approaches to scientific progress: the epistemic approach (e.g. Bird 2007), the semantic approach (e.g. Niiniluoto 1980; 2014), and the noetic approach (e.g. Dellsén 2016; 2021). The epistemic approach defines scientific progress in terms of knowledge. The semantic approach construes scientific progress in terms of truthlikness. The noetic approach characterises scientific progress in terms of understanding. According to the epistemic approach, science progresses if scientific knowledge accumulates. According to the semantic approach, science progresses if more scientific truths are obtained or scientific theories are approximating truths. According to the noetic approach, science progresses if there is an increased understanding of some phenomena, where understanding is defined in terms of accuracy and comprehensiveness of dependency models.[11] I will argue that the new functional approach has an important advantage over these approaches: it provides a fuller picture of progress in the history of science.

It has been shown that the new functional approach better accounts for progress in genetics (Shan 2019; 2020a) and conservation biology (Justus and Wakil 2021) than the epistemic and semantic approaches.[12] In particular, I argue that the new functional approach is better than the epistemic, semantic, and noetic approaches in accounting for the non-theoretical aspect of scientific progress. All of the epistemic, semantic, and noetic approaches to scientific progress pay too much attention to theoretical achievements: is there more propositional knowledge than before? Are our current best scientific theories more truthlike? Do we have more accurate and comprehensive dependency models? However, such approaches downplay the significance of the non-theoretical aspect of science. Scientific practice is much more than theorising or modelling. It would be surprising if the introduction of new research problems and the improvement of the experimental methods and devices are excluded from the constituents of scientific progress. Consider the case of the origins of genetics. It seems plausible to argue that the progress made by Mendel was to propose the law of composition of hybrid fertilising cells to advance our knowledge of the mechanism of heredity. Similarly, de Vries' law of segregation, Correns' Mendelian rule, and Bateson's Mendelian principles provide a better knowledge of heredity than Mendel's law. Yes, it can be argued that we knew more and more about the mechanism of heredity with the theoretical development from Darwin to Bateson. However, it is definitely not the only aspect of the progress achieved in the study of heredity in that period. We learnt more and more about how to define good research problems, how to design and undertake good experiments, and how to use these problems and experiments to study the mechanism of heredity in a better way. In a word, the non-theoretical aspect of scientific progress should be taken into account as well as the theoretical aspect. As Heather Douglas (2014, 56) points out, science is not just about theory. Hence, scientific progress should be examined in both theoretical and non-theoretical aspects. Unfortunately, not all of these non-theoretical activities can easily be accounted for in terms of propositional knowledge, theories, or dependency models. Thus, I contend that my functional approach provides a better account of the non-theoretical aspect of scientific progress.

In addition, the epistemic, semantic, and noetic approaches are even more problematic when they are applied to some sciences in which theorising is not a key task. As James Justus and Samantha Wakil (2021, 189) argue, '[the epistemic and semantic approaches] seem utterly ill-equipped to account for progress in applied, ethically-driven sciences. These sciences don't deliver anything resembling justified true beliefs about a mind-independent cosmos, at least as that idea is usually philosophically expressed about, say, particle physics. Instead, they supply data-driven, evidence-based, and in the present instance algorithmically-rigorous means for achieving ethical goals.' Such an objection is also applied to the noetic approach, since understanding is determined by accuracy and comprehensiveness of dependency models. In contrast, the new functional approach better accounts for progress in these sciences. It can well characterise the main activities in applied, ethically-driven sciences (i.e. 'delivering scientific insights and tools that promote achieving ethical goals') in terms of problem-defining and problem-solving.

Moreover, all the epistemic, semantic, and noetic approaches focus too much on the explanatory activities in scientific practice. This is rooted in a theory-centric view widely received in philosophy of science. As C. Kenneth Waters summarises,

> Philosophers (perhaps I should say we) typically analyze [science] by identifying central explanatory theories. Then for each theory, we analyze its central concepts and principles (or laws), detail how it can be applied to explain the phenomena, reconstruct how it is justified, explore how it might be further developed or how its explanatory range might be extended (the so-called 'research program'), and consider how it should be interpreted (for example, instrumentally or realistically). (Waters 2004, 784)

However, this kind of philosophical analysis overlooks the significance of investigative or exploratory activities in scientific practice. Science not only aims to explain puzzling phenomena, but also aims to investigate them 'towards open-ended research' (Waters 2004, 786). As Waters (2004, 786) insightfully points out, scientific practice often 'aimed towards developing knowledge about phenomena which fall outside the domain, even the potential explanatory domain, of any existing theory.' It is evident that none of the epistemic, semantic, and noetic approaches captures this investigative aspect of scientific progress. In contrast, by highlighting the significance of problem-defining, the new functional approach sheds light on the investigative or exploratory feature of scientific practice.

4. Objections and Responses

In this section, I address two objections to my new functional approach.

4.1 Problem of Compromise

One objection arises from a concern that the new functional approach seems to be too friendly to the epistemic and semantic approaches. As my reply to the problem of counter-intuition involves the notions of truth and knowledge, one may wonder whether my approach can be still classified as 'functional' rather than epistemic or semantic. It seems that my new functional approach can be reinterpreted in the way that science progresses if more and more know-how is attained, or that science progresses if more perspective-dependent truths are obtained. As Ilkka Niiniluoto complains,

> [Shan] is open to the introduction of the notions of know-how and perspectival truth, so that his "new functional approach" is a compromise with what Bird (2007) calls the "epistemic view" of progress. (Niiniluoto 2019)

In response, I argue that my functional approach is not reducible to the epistemic or the semantic approach. As I have pointed out, the solution to a research problem is not something purely theoretical or propositional. There are some indispensable non-theoretical aspects. For example, problem-specification and experimentation cannot be reduced to knowledge, truth, or other theoretical elements. Accordingly, I do not see that there is any true or correct solution to a research problem, given its practical nature. For example, it is implausible to claim that there is a true or correct way of experimentation or problem-refining. Moreover, I would like to highlight that my approach aims to capture the multiple facets of scientific progress, but it does not imply that the functional, epistemic, and semantic aspects constitute the nature of scientific progress in equal shares. Rather more know-how (the epistemic aspect) and more well-corroborated hypotheses (the semantic aspect) may only partially constitute usefulness of problem-defining and problem-solving (the functional aspect). In short, both the epistemic and semantic accounts of scientific progress can be explained by the new functional approach, but the new functional account cannot be fully accounted for in terms of knowledge or truthlikeness. Therefore, there is no compromise between the epistemic and the new functional approaches. Nor is the distinction between the epistemic and new functional approaches blurred. As I have argued in section 4, the new functional approach is better than both the epistemic and semantic approaches.

4.2 Problem of Problem-solving Centrism

Another objection is that the new functional approach still assumes the central role of problem-solving in scientific practice, so it will be challenged by the similar problems that the Kuhn-Laudan approach encounters.

> Yafeng Shan (2019) has recently offered a version of the functional-internalist approach that seems to me to be an improvement on the Kuhn–Laudan version. Nonetheless, I think it still fails on the point raised in this paragraph, that not all progress involves solving a problem. (Bird 2022, 42 f2)

> In Shan's new functional approach to scientific progress, too, the notion of the *solved problem*, which is the basic unit of scientific progress according to Laudan's problem-solving model of progress, is central. (Mizrahi 2022, 3)

However, as I have highlighted in section 3, problem-defining and problem-solving are two mutually intertwined activities. They cannot be analysed in isolation in the examination of scientific progress. Unlike the Kuhn-Laudan approach, my new functional approach does not view science as an essentially problem-solving enterprise. Accordingly, problem-solving success is not central to the new functional approach, while usefulness of exemplary practices is.

5. Conclusion

In this chapter, I have argued that the functional approach should not be conflated with the Kuhn-Laudan functional approach. There are other versions of the functional approaches, such as the Popper-Lakatos approach and my new functional approach. I have also argued that my new functional approach is the most promising version of the functional approach. I have shown that this new functional approach is immune to the main objections to old functional approaches. Moreover, I have argued that the new functional approach is better than the epistemic, semantic, and noetic approaches by providing a fuller picture of scientific progress. In a word, scientific progress is best characterised in terms of usefulness of exemplary practices.

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[1] The differences between Kuhn’s and Laudan’s approaches are marginal, whereas their similarities are quite fundamental. Thus, it is plausible to regard Kuhn’s and Laudan’s approaches as the same version of the functional approach.

[2] A typical example is the neglect of Mendel’s work. For an in-depth analysis, see Shan (2020a chapter 7).

[3] It should be noted that Popper (1963) also developed the concept of verisimilitude which later played a central role in the semantic approach to scientific progress (see Chapter 3). Thus, it can be argued that Popper pioneered both the semantic and functional approaches.

[4] The Popper-Lakatos approach is largely neglected in the recent discussion on scientific progress. Only Bird (2007) and Shan (2019; 2020a) briefly mention it as a version of the functional approach. What is worse, there is little detailed examination of it. Bird (2007, 67) simply dismisses it without argument: ‘Much of what I have to say will apply to Lakatos’s methodology of scientific research programmes also.’ However, as I shall argue, the Popper-Lakatos approach is immune to some objections to the Kuhn-Laudan approach.

[5] It seems appropriate for Bird (2007, 67) to call these approaches ‘functional-internalist’.

[6] For more discussion on the distinction between macro- and micro-scientific consensus, see Shan (forthcoming).

[7] For an overview of the Mendelian-Biometrical controversy, see Mackenzie and Barnes (1975) and Shan (2021).

[8] See more discussion on interdisciplinary progress in chapter 19.

[9] Jason Stanley and Timothy Williamson (2001) famously rejects this distinction by arguing that know-how is reducible to know-that. Whether there is a genuine distinction between how-that and know-how, my point still holds. Science does not only tell us something theoretical which can be formulated in the propositions, but also tell us something practical, whether which can be reformulated in the propositions or not.

[10] It should be highlighted that the notion of usefulness can be explicated by the contextualist theory of truth does not imply that my functional approach assumes a contextualist theory of truth. It does not eliminate the possibility that it can also be explicated by other theories of truth.

[11] This is Finnur Dellsén’s most recent formulation of his noetic approach (Dellsén 2021), which is different from his early formulation (Dellsén 2016). According to the early formulation, ‘Science makes (cognitive) progress precisely when scientists grasp how to correctly explain or predict more aspects of the natural world than they did before’ (Dellsén 2016, 75). Dellsén’s early version is more similar to the functional approach, while his recent one is closer to the semantic approach.

[12] It is also argued that my functional approach well characterises progress in other scientific disciplines, such as economics (see chapter 12), seismology (see chapter 9), and interdisciplinary sciences (see chapter 19).