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The Function of Scientific Concepts

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Abstract
The function of concepts must be taken seriously to understand the scientific practices of developing and working with concepts. Despite its significance, little philosophical attention has been paid to the function of concepts. A notable exception is Brigandt (2010), who suggests incorporating the epistemic goal pursued with the concept's use as an additional semantic property along with the reference and inferential role. The suggestion, however, has at least two limitations. First, his proposal to introduce epistemic goals as the third component of concepts lacks independent grounding, except to account for the rationality of semantic change (the Grounding Problem). Second, it is hardly justified to consider epistemic goals as a semantic property (the Misplacement Problem). To remedy these predicaments, we suggest a new perspective that takes concepts as cognitive entities with a 2-layered structure rather than as merely linguistic entities and develop an account of the function of concepts. We provide empirical evidence showing that functional information affects our cognitive processes. It is claimed that the function of concepts is not a semantic property but a type of meta-information regulating a body of concept-constitutive information.

Keywords Scientific concepts · Function · Epistemic goals · Semantic approach · Cognitive approach

1 Taking the Function of Concepts Seriously

Science is a goal-directed activity. Scientific activities aim to discover or create new phenomena, explain known phenomena, predict novel events, or control the world. In a similar vein, scientific concepts are created and utilized to serve specific investigative objectives (Feest & Steinle, 2012; Nersessian, 2008). Consequently, understanding the investigative practice involving scientific concepts necessitates the serious treatment of the goals or func-

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tions of the concepts. The first step is to provide an outline of what the function of a concept is and to delineate the roles it plays. Roughly speaking, the function of a concept is what it is supposed to do in scientific practice within a relevant scientific community.

The function of scientific concepts can play descriptive, normative, and explanatory roles. First, by recognizing the function, we can better understand scientific practices by illuminating what scientists seek to achieve through the concept's uses. The function plays a descriptive role, enabling us to provide more accurate descriptions of scientific endeavors. Second, the function of a concept provides the norm against which different applications of the concept are evaluated. This norm pertains to what the concept is supposed to achieve. If a particular concept fails to perform the function that it is supposed to perform, it will be subject to negative evaluation. Third, it helps account for the rationality of conceptual changes and variations. When an investigative practice that makes use of a concept receives unfavorable evaluation, it provides a compelling reason to revise the concept. For example, the concept of orbit was introduced during the so-called Copernican Revolution. With the concept, astronomers attempted to obtain both accurate predictions and physical explanations (Barker, 2002; Donahue, 2006; Goldstein & Hon, 2005). They wanted to predict the planet's paths more accurately and explain them in terms of physical causes. Thus, the concept had its own function, which provided a norm for its uses. Understanding the function allows us to evaluate and explain the conceptual change that occurred during the revolution in modern astronomy.

Despite its significance, the function of concepts has drawn little attention from philosophers of science, with a notable exception of Brigandt (2010), who emphasizes the epistemic goal pursued by a term's use.[1] Since his framework of scientific concepts can serve as a good starting point, I begin by introducing his analysis and suggestion in Sect. 2. However, his proposal is not without problems. I aim to make progress by overcoming the limitations of his proposal. To do so, in Sect. 3, I scrutinize Brigandt's suggestion and identify two problems (Misplacement and Grounding). To avoid these problems, I suggest an alternative approach – the cognitive approach – to scientific concepts in Sect. 4. The remainder of this paper offers a solution to problems by developing a generalized etiological notion of function (Sect. 5) and presenting independent, psychological reasons for introducing function into concepts (Sect. 6).

2 Epistemic Goals as the Third Component of Concepts

Traditionally, philosophers have distinguished the content of a concept into two dimensions: its reference (what the concept refers to) and its inferential role (the sense or meaning of the concept). However, Brigandt (2010) proposes a third dimension, the epistemic goals pursued by a concept's uses. He claims that incorporating epistemic goals as one of the

[1] Interestingly, there has been a noteworthy shift in recent literature on conceptual engineering, as scholars have begun to emphasize the conceptual or linguistic function, which can serve explanatory or normative purposes (Simion & Kelp, 2020; Riggs, 2021; Thomasson, 2022). For a critical discussion, see also Cappelen (2018). It should be clear that this paper primarily pertains to the realm of philosophy of science rather than conceptual engineering. Furthermore, the basic idea underlying this article stems from my doctoral dissertation on scientific concepts (Cheon, 2014), which preceded the recent surge of interest in function among conceptual engineers.

semantic properties of concepts, alongside reference and inferential role, provides a more comprehensive understanding of scientific practices involving the concepts.

While it is evident that scientists pursue a variety of epistemic goals, it does not imply that these goals are constitutive of the content of specific concepts. Thus, it becomes crucial to establish criteria for determining when an epistemic goal qualifies as a semantic component of conceptual content. Brigandt argues that the epistemic goals associated with a concept are considered a semantic property in cases where the goal is directly tied to that individual concept in the sense that "the rationale for the introduction or continued use of a central theoretical concept is to pursue this epistemic goal" (Brigandt, 2010, 23). For example, in the early 20th century, biologists aimed to predict the patterns of inheritance by using the classical gene concept (Carlson, 1966; Waters, 1994). Because this epistemic goal was directly tied to the concept of the gene, the goal counts as a component of the semantic content.

Brigandt's suggestion is motivated by a desideratum that any theory of scientific concepts is intended to meet: to account for the rationality of conceptual changes or revisions. By incorporating the third component, Brigandt argues, a suitable framework of scientific concepts can be achieved. The question is how epistemic goals serve to account for such rationality. Brigandt illustrates the case of the gene concept by considering the historical transition from the classical gene concept to the molecular gene concept. Instead of delving into the details of this particular case, I opt to present a schematic illustration of how the basic idea works.

First, there are simple cases in which epistemic goals remain unchanged while the inferential roles or references of concepts change. When epistemic goals are fixed, revising the concepts can be evaluated by estimating the extent to which such a revision better fulfills these goals. Changes in concepts are regarded as rational if the revised versions of concepts meet the goals to a higher degree than the original version.[2]

Second, things become more complicated when the goals themselves undergo changes. For the conceptual change in these cases to be rational, it is required to demonstrate the reasonableness of the changes in epistemic goals. There are two reasonable patterns for reformulating epistemic goals associated with a scientific concept. One possibility is that when a theory that includes the concept as a central element turns out successful, scientists strive to expand the theory by directing their attention toward unexplored phenomena. Given the newly established theoretical agenda, a concept can be assigned new or more specific goals based on the consensus within the research community. The change from the classical gene concept to the molecular gene concept, as Brigandt nicely illustrated, provides a notable example illustrating this pattern (Brigandt, 2010; Waters, 1994). Once biologists with the classical gene concept successfully predict the inheritance patterns, they redirect their attention toward phenomena at the molecular level. Using the molecular gene concept, they aimed to explain how DNA sequences code for different molecular products, such as RNAs and polypeptides (Weber, 2005).

Another possible situation in which it is reasonable to reformulate the epistemic goals arises when the theory in which the concept plays a crucial role encounters empirical failures

[2] This kind of evaluation depends on the instrumental conception of rationality. Some might wonder whether rationality can be understood completely in terms of a means-ends analysis. However, the debate about whether epistemic rationality is reducible to instrumental rationality is another issue (see Siegel, 1996; Kelly, 2003; Laudan, 1990).

or a dim prospect for success. Here, the success or failure of a theory is evaluated in relation to its competing theories against their historical background. In such cases, the concept may be discarded alongside unsuccessful theories (e.g., the phlogiston concept). However, there are instances where the concept can be preserved by selectively eliminating a limited set of goals from the original set. For example, let us consider the oxygen concept introduced by Lavoisier during the chemical revolution. Initially, the concept was utilized to explain combustion, calcination, and acidity, with 'oxygen' etymologically meaning the principle of acidity. However, in the early 19th century, it was discovered that oxygen was unnecessary for being an acid. Consequently, Lavoisier's view of acidity was abandoned. Nonetheless, the oxygen concept endured a remarkable transformation. Instead of jettisoning the concept altogether, scientists continued to use the concept while relinquishing the epistemic goal of explaining acidity (see Chang, 2004; 2009). In short, if epistemic goals remain unchanged or change reasonably, they serve to account for the rationality of conceptual revisions.

3 The Problems of Grounding and Misplacement

Brigandt's idea is a valuable contribution to philosophical investigations of scientific concepts: any framework of scientific concepts must seriously consider the epistemic goals pursued with concepts. He aptly highlights that the changes in the inferential role and even reference of a concept can be rational when they are explained by the stability (or gradual, stepwise change) of epistemic goals. Furthermore, by considering the goals, we can achieve insights into the factors driving the conceptual changes that occurred in the history of science, science education, and child development. Scientists are inclined to make changes to their concepts when they believe such changes will improve their epistemic goals. Upon close analysis, however, his framework of concepts is not entirely satisfactory. In this section, two problems will be discerned: the Grounding Problem and the Misplacement Problem.

First, Brigandt urges the introduction of the third component "as an additional semantic property of a term (…) because it accounts for the rationality of semantic change and variation" (Brigandt, 2010, 37). Aside from this purpose, however, he provides no independent grounds for introducing epistemic goals as an additional component of concepts.[3] Let us call this the Grounding Problem. We often stipulate theoretical posits to solve particular problems (e.g., accounting for the rationality of conceptual changes), but this leaves open whether the posits are grounded in reality or merely fictional. Brigandt's account does not answer whether the epistemic goals or functions are merely instrumental or not.

Second, according to Brigandt, the epistemic goals associated with a concept are semantic in character. It is curious, however, to treat the epistemic goals as a "semantic" property. On the one hand, such treatment is hardly justified insofar as the semantic properties concern the relationship between linguistic expressions and what they express. On the other hand, if the goals are not a semantic component, it is unclear what they are and how they

[3] One reviewer points out that Brigandt is motivated to build on Brandom's pragmatic account of concepts and thus accounting for the rationality of conceptual changes is not the only reason for introducing the third element. However, this paper concerns whether the introduction of function is well grounded in (psychological) reality.

should be treated alongside reference and meaning (or inferential role). The failure to correctly locate the goals or functions can be referred to as the Misplacement Problem.[4]

I hypothesize that the predicaments mentioned above are rooted at least partially in the long shadow of the traditional, semantic approach to scientific concepts. Traditionally, the philosophical treatments of conceptual change have focused on the semantic content of theoretical terms. In particular, the debates about the incommensurability thesis and its philosophical implications for scientific realism or progress have centered around meaning change and the referential (dis)continuity of central terms in competing theories (Kuhn, 1962; Putnam, 1975; Sankey, 1994; Scheffler, 1967).

There is some evidence suggesting that Brigandt is an unwitting victim of the semantic approach. First, he uses "concepts" and "terms" interchangeably. Sometimes, he mentions "the epistemic goals pursued by a *concept's* use"; other times, he describes "the epistemic goals pursued by a *term's* use." In his paper, concepts are roughly identified with the semantic content of (theoretical) terms. Second, he conflates the conceptual with the semantic when he claims that epistemic goals are one of "three semantic properties," one of "three components of content," and "the third component of conceptual content." It seems that he offers no clear distinction between the conceptual and the semantic content.

Although a knock-down argument against the semantic approach cannot be presented here, I provide two reasons why it has dim prospects. The bottom line is that there is no consensus on how to determine the semantic content of concepts. According to descriptivism, the content of a concept is the way in which the concept is used. However, whether the content of a concept is determined by the way the concept is used has not been settled. Externalism states that the content of a concept is not determined by the way in which the concept is used.[5] Unfortunately, the debate between descriptivism and externalism has not been resolved (and is not likely so). One might appeal to detailed (historical or contemporary) case studies to resolve the debate. Nevertheless, this process does not solve all the problems since there are multiple ways of reconstructing the cases depending on different views of content determination (for an overview of the semantic and alternative approaches to scientific concepts, see Cheon & Machery, 2016).

Second, the semantic framework leaves no room for goals or functions. For Brigandt, epistemic goals are introduced for the sole purpose of supporting the rationality of semantic changes, not from investigating the nature of concepts. The lack of a detailed account of epistemic goals seems to originate from the fact that goals or functions have no natural place in the semantic framework. His adoption of the semantic approach helps us understand why he takes the goals as a semantic component. If epistemic goals are assumed to be one of the linguistic properties of terms and if these goals are neither syntactic nor pragmatic, the

[4] Relatedly, Brigandt provides no detailed account of epistemic goals. Of course, as he mentions, the goals are assigned collectively by a group of scientists during a particular period of time. Still, there is no explanation for what the goals are like or how to identify and individuate them. For example, Brigandt correctly notes that the epistemic goal pursued by the use of the gene concept in classical genetics was to predict inheritance patterns. Given that geneticists pursued several epistemic goals (e.g., understanding the biological world), it is unclear how an epistemic goal became tied to a particular concept.

[5] As one reviewer pointed out, we can make the characterizations of descriptivism and externalism more precise. For example, we can draw the distinction between the definite description theory of reference of proper names and the use theory of meaning. Additionally, we can distinguish the pure causal theory of reference from more nuanced versions like causal-descriptivism. However, while acknowledging that the distinction made above may be somehow simplistic, I believe that they suffice for our purposes of discussion.

only remaining option is that they belong to semantic content. In short, epistemic goals are unnaturally inserted into the semantic framework.

In the remainder of this article, I will develop an account of the functions of scientific concepts to solve the problems of Grounding and Misplacement.

4 Scientific Concepts as Cognitive Entities

To overcome the shortcomings of the semantic framework, I suggest an alternative approach to scientific concepts – the cognitive approach – which will be elaborated below. This approach is not entirely new since leading philosophers during the historical turn have relied on Gestalt psychology (Kuhn, 1962/1970; Hanson, 1958). Still, the philosophical discussion of scientific concepts was divorced from the psychology of concepts. Not until the 1980s did philosophers make use of the burgeoning psychological literature on concepts (Thagard, 1986; Nersessian, 1989; Andersen et al., 2006). Those philosophers attempted to shed new light on conceptual changes in science by paying attention to empirical studies of concepts. Thagard (1990, 256) succinctly summarized the basic idea of the cognitive approach as follows: "the nature of concepts and conceptual change is in fact an important epistemological topic and […] drawing on ideas from the cognitive sciences can provide an account of conceptual change for epistemology and the philosophy of science."

Taking this approach, I propose thinking of a concept as a body of information or an information-complex.[6] Let me introduce an *individual scientist's concept* of x as follows:

(ISC) An individual scientist's concept of x is an information-complex about x that is stored in long-term memory and that is used by default in the cognitive processes underlying scientific practices dealing with x.[7]

Some clarification is in order. First, this characterization is based on the mental representation view on concepts, according to which a concept of x is a mental representation of x (Margolis & Laurence, 2007). However, to sidestep metaphysical disputes on the nature of representation, I take a concept of x as an information-complex used in the scientist's cognitive processes underlying investigative practices dealing with x. For example, the planet concept of a scientist is the mental representation or the information-complex about planets, which is used in her cognitive processes underlying various investigative practices dealing with planets. Second, not all information concerning x constitutes the concept of x. Even if a scientist relates 'look beautiful in the night' to planets, it does not mean that 'look beautiful in the night' is a constitutive component of the planet concept. Only the information that is retrieved and used by default is regarded as part of the concept of x (Machery, 2009; 2017).

Given the collective nature of scientific practices, I propose conceiving a *scientific concept* as the shared property of scientists of a community, which is learned, preserved, and

[6] Infamously, there is no agreed-upon definition of information, and it has different meanings in different contexts. For the sake of argument, it is enough to adopt the data-based definition: information is well-formed and meaningful data (Floridi, 2011). By "information-complex", I mean a structured body of information instead of a mere collection of information.

[7] It should be obvious that I apply Machery (2009)'s characterization of ordinary concepts to scientific contexts, as he articulates how the theoretical term "concept" is used in the psychological literature: "A concept of x is a body of information [knowledge] about x that is stored in long-term memory, and that is used by default in the processes underlying most, if not all, higher cognitive competence when these processes result in judgments about x" (Machery, 2009, 12).

transmitted within the community. From this perspective, a concept created by a scientist does not count as a scientific concept until it is collectively accepted by the relevant scientific community. Now, the notion of a *scientific concept* can be formulated as follows:

> (SC) A scientific concept of x is an information-complex about x, shared among competent members of a relevant scientific community, which is used by default in their cognitive processes underlying scientific practices dealing with x.

Note that the scientific concept of x is a collective notion. Specifically, only the shared components of individual scientists' concepts of x constitute the scientific concept of x.[8] For example, biologists who used the classical gene concepts had common ideas, such as the distinction between genotype and phenotype and basic principles specifying the gene transmission, but had different conjectures on the internal, material structure of genes (Carlson, 1966). Consequently, information on internal structure was not considered part of the *scientific concept* of the gene. Simply put, a scientific concept of x is an information-complex of x shared by competent scientists's concepts about x. Our focus in this paper lies in understanding scientific concepts as a collective notion rather than exploring individual scientists' concepts.

Still, this characterization contains an abstract and rough idea that can be implemented in various ways. For example, Thagard treated a concept as a schema representing a category, a property, or a situation. A schema is a complex information structure organized by specifying slots (for particular aspects of the world) and values for each slot (Minsky, 1975). Alternatively, Andersen and colleagues (2006) adopted a dynamic frame model of Barsalou (1992) as a tool for investigating historical episodes like the Copernican Revolution. This paper will remain neutral on which forms of implementation would be better.

Furthermore, I propose that a concept as an information-complex has a two-layered structure: (the 1st-order) information and meta-information. Meta-information can be understood by analogy to metadata since the notion of metadata is widely used in information technology and library science (NISO, 2004; Gilliland, 2008). Metadata is data about data. For example, when you take a picture with your smartphone, the pixel data for the image are stored along with metadata about the date the image was created, the file size, and the exposure time. Metadata is important because they make it easier to retrieve, use, or manage object data. Thus, as the volume of data to be managed grows, scientists increasingly rely on metadata. Similarly, meta-information (MI, in short) is information about information. MI is something about information in that it describes or explains the 1st-order object information, thereby enhancing the ease of retrieval, utilization, and management of the object information. Furthermore, MI qualifies as information in accordance with the data-based definition of information (see footnote 6). Not only does MI represent certain aspects of information stored in concepts, but it concerns why and how the 1st-order information is

[8] One reviewer raised a question like: "if concepts are bodies of information, then how do we account for two people having the same concepts?" My answer is two-folded. First, given that my view is based on mental representation view of concept, the sameness of the represented makes for the sameness of concepts of two people. For example, Bob's concept of x and Sally's concept of x can be the same in that both of them are about x. Second, even if Bob's information-complex about x is different from Sally's information-complex about x, they have the same *scientific concept* of x when they are two competent members of a scientific community. The question of who qualifies as a competent member needs additional treatment, which goes beyond the scope of this article.

represented. Thus, MI puts constraints on which information can be retained, organized, and structured in a particular concept.

MI can be divided into three distinct types: structural, material, and contextual meta-information. Structural MI tells us how an information-complex is organized[9]; material MI encodes the subject matter of a given information-complex (i.e., what the information-complex is about); and contextual MI concerns the contexts in which the information is generated and used (e.g., when, where, and by whom). Among these contextual factors, the function of concepts operates as a crucial element of contextual MI. Unlike other contextual factors that happen to be related to the information, functional MI is unique by playing a regulatory role. By encoding information of "for what" the 1st -order information is used, it guides us in organizing the information-complex of x for storing, retrieving, and utilizing. Consequently, I propose that the function of concepts is to serve as contextual regulatory MI, ensuring coherent and purposeful handling of information. Nonetheless, I do not argue that every concept has its own function. Instead, I maintain that if a concept has a certain function, it operates as a form of MI.

This suggestion can be taken as a response to the Misplacement Problem, which can be couched in terms of the following dilemma: while the epistemic goals associated with a concept are not commonly regarded as part of its semantic content, their status remains unclear if they are not semantic. In this section, I suggest a scientific concept is an information-complex with a 2-layered structure. Now, we can take the function of a concept as a piece of MI associated with an information-complex. Epistemic goals or functions are not semantic in character but have the unique status as a regulatory MI. To complete the answer, beyond the brief outline presented here, the consequent sections will delve into the explication of the functions of concepts and their role in our cognition, thereby solving the Grounding Problem as well.

5 A Generalized Etiological Notion of Functions

By distancing ourselves from the semantic framework, we can develop a substantial account of functions applicable to scientific concepts. The etiological notion of functions fits well with the cognitive approach presented above. From the etiological perspective, functions are explained in terms of the history of selection. In its simplest form, as described by Wright (1973, 1976), "the function of X is that particular consequence of its being where it is which explains why it is there" (1976, 78).

(WF) The function of X is Z if and only if (i) Z is a consequence of X's being there and (ii) X is there because it results in Z.

In this definition, the function as selected effects explains why a certain activity or effect rather than others is regarded as the proper function of a system and enables us to understand why such a function exists. Of course, the etiological notion is not the only game in town. Cummins (1975) advanced another account of functions, which concerns a particular

[9] Philosophers of science tend to adopt a particular theory of concepts. However, when it comes to considering the cognitive science of concepts in its entirety, we observe that different theories of concepts are still competing (Murphy, 2002; Prinz, 2002; Machery, 2009). Various theories assume different structural MI about how concept-constitutive information is organized. Cheon and Machery (2016) argues for the structural heterogeneity of scientific concepts.

explanation called functional analysis. Functional analysis applies when someone attempts to explain the overall dispositions or capacities of a complex system by a set of simpler sub-capacities of components. The function of this component is the sub-capacities that contribute to the overall capacity. Thus, functional analysis explains how a system can have the capacity by referring to the functions of sub-systems. Notice that the two accounts have different explanatory strategies and different explananda (Griffiths, 1993; Millikan, 1989). In order to avoid terminological confusion, we can call the two explanans the proper function and the functional role, respectively.

The proper function of a scientific concept concerns why a research community creates and uses the concept in its investigative practices. For example, the proper function of the gene concept in Mendelian genetics was to predict the patterns of inheritance. On the contrary, the functional role of a concept is something that contributes to the overall epistemic capacities of the scientific practices in which the concept figures.[10] This paper emphasizes the proper function of concepts, which roughly corresponds to Brigandt's epistemic goals. Next, we pursue an etiological notion of function that can be applied to concepts.

Despite its advantage of simplicity, Wright's analysis must be elaborated on for two reasons. First, his analysis offers little constraint, so the ascription of function can be too permissive (for counterexamples, see Boorse, 1976).[11] Second, an appropriate account of function should allow for changes in function. Vestigial traits enable us to make a distinction between evolutionary and functional explanations of a trait. This distinction marks a difference between explaining what built the trait originally and why the trait has recently been maintained in a selective context. It suggests that functions concern the recent maintenance of a trait rather than the origin (Godfrey-Smith, 1994).

By responding to counterexamples and accommodating the distinction between the origin and the recent maintenance of a trait, philosophers have developed sophisticated accounts of functions (Millikan, 1984, 1989; Griffiths, 1993; Godfrey-Smith, 1993, 1994). Despite their diversity, these accounts are geared toward versions of an etiological notion of biological function, and the common idea can be summarized by the following three conditions.

> The (etiological) function of x is Z if and only if:
> (EF1, Family) x is a member of a reproductively established family X;
> (EF2, Selection) past members of X were selected in the recent past because they did Z and, by doing so, they positively contributed to the fitness of the biological system they belonged to; and.
> (EF3, Explanation) the fact that members of X were selected because they did Z explains why members of X, such as x, exist now.

We are now in a position to generalize the etiological notion for application outside the biological domain. One might be skeptical of the unified definition of functions across vari-

[10] Nerssessian also addresses the function of concepts when she states that the function of the electromagnetic field is to transmit electromagnetic actions through space (Andersen & Nersessian, 2000, S235). However, it remains ambiguous whether it pertains to the proper function or the functional role, and whether it is the functional role of the concept of electromagnetic field or the functional role of its reference (the electromagnetic field).

[11] Consider a fast-moving stream in which a small rock supports a larger rock: without the small rock, the larger rock would be washed away. In Wright's analysis, the small rock's function is supporting the larger rock because it is what the small rock does and explains why it is there.

ous domains since there are indeed some differences between the functions of biological systems and artifacts (Vermaas & Houkes, 2006). It is often claimed that they differ in terms of the units to which the functions are ascribed (organs as parts of a whole system or artifacts themselves) and based on whether the human intention is involved or not. The subtle differences, nonetheless, do not prevent us from pursuing a general account of functions at a more abstract level of analysis. A generalized etiological notion of function can be achieved by replacing the conditions above with the following ones:

> The (etiological) function of x is Z if and only if.
> (EF1*, Family*) x is a member of a *developmentally* established family X;
> (EF2*, Selection*) past members of X were selected in the recent past because they did Z or were expected to do Z best and, by doing so, they positively contributed to the continuation or expansion of the system they belonged to; and.
> (EF3, Explanation) the fact that members of X were selected because they did Z explains why members of X exist now.

This generalized notion applies not only to biological function but artifact function and the function of concepts. Before we apply this notion to scientific concepts, some clarifications are in order. First, EF1* requires that the variants of x form a family which has been established by developmental processes in a broad sense, including reproduction by mating, historical processes, and child development.[12] Second, two modifications are made to EF2*. The focus on the biological system and its reproductive success has been extended to encompass the system in general and its continuation and expansion. Further, the successful selection of members can be made based on their actual performance (demonstrated ability to perform Z) or their expected competence in performing Z.[13] This modification is beneficial because it allows us to accommodate cases such as the oxygen concept, where the function of the concept had included an explanation of acidity. The concept was selected because it was expected to explain various phenomena concerning acidity, even though it later turned out to be unnecessary. We can now apply the generalized notion to the classical gene concept.

> The function of the classical gene concept is to predict the inheritance pattern:
> ($EF1^*_{GENE}$) the various uses of the gene concept constitute a family;
> ($EF2^*_{GENE}$) the past uses of the gene concept were selected because they were expected to predict the inheritance pattern and successfully did so and, by doing so, they positively contributed to the continuation of the investigative system (i.e., classical genetics); and,

[12] A reviewer expressed concern about the inclusion of child development narrowing the scope by emphasizing human biology. However, it is not accurate. The modification in the first condition consists of the shift from a *reproductively* established family (EF1) to a *developmentally* established family (EF1*). While history (EF1) previously referred to a selective context, the developmental process in a broad sense (EF1*) encompasses not only the history of natural selection but the human history, science education, and child development. Consequently, the notion of a *developmentally* established family should be understood as an extended notion of a *historically* established family.

[13] This type of selection can be referred to as "virtual selection." It describes the collective processes by which people contemplate several competing alternatives and select one based on their best estimate of expected competence. Although virtual selection differs from actual selection, the two forms of selection are similar enough for our purposes.

(EF3 $_{\text{GENE}}$) the fact that the past uses of the gene concept were selected because of their successful prediction explains why the gene concept exists there.

I neither put forth an entirely new definition of function nor claim any novelty of the etiological notion of the function itself. Still, I maintain that changing the perspective makes it easier to make the etiological notion of function applicable to psychological entities like concepts. By articulating the etiological notion, we accomplish a clear understanding of what the functions of concepts are.

6 Independent Ground for Reality?

The Grounding Problem refers to the need of independent grounds for considering functions beyond the sole purpose of accounting for the rationality of conceptual variations. By taking concepts as cognitive entities with internal structure, we discover some evidence suggesting the psychological reality of the functions of concepts. Notably, recent psychological research indicates that when people learn and use some concepts, they know what the concepts are used for and that the knowledge of this function affects cognitive processes. I will present some evidence derived from two sorts of empirical studies of experimental psychology. However, it is worth noting that the empirical studies presented below were not conducted in accordance with my proposed framework that treats the functional information as a metainformation and adopts the generalized etiological notion of function. Nonetheless, they illustrate how functional information ("for what" information) influences other components within an information-complex.

The first sort of evidence shows that functional information affects people's typicality judgments. Experiments on categorization and induction have shown that not all members of a category are equal, such that some members are more typical than others. For example, in North America, robins are typical birds, while penguins are not. This phenomenon, known as the typicality effect, has led many psychologists to abandon the classical view of concepts, which takes a concept to be a set of necessary and sufficient features. Then, what makes something typical or atypical? Although several explanations have been put forth, recent psychological experiments show that ideals play important roles in determining how typical a given instance of a category is.

Ideals are said to be the desirable instances that best fulfill the function associated with a category. Whether and how an instance counts as an ideal depends on the extent to which it fulfills the associated function. For example, an ideal for "things to eat on a diet" is zero-calorie food because such food maximally fulfills the function of losing weight. Ideals turn out to influence the typicality judgments people make. Psychologist Barsalou (1985) showed that the graded structure of goal-derived categories (e.g., clothing to wear in the snow) is primarily determined by ideals (e.g., how warm it keeps people) rather than by familiarity or central tendency. The effects of ideals were found in goal-derived categories and common taxonomic categories. For example, the typicality of a vehicle is determined by how efficient the vehicle is for transportation. People reported that the most typical vehicles are the ones that are viewed as efficient means of transportation (Barsalou, 1985).

These findings hold even in natural categories. Lynch and colleagues (2000) conducted a study examining the typicality judgment about various tree categories made by tree experts (taxonomists, landscapers, and park maintenance personnel) and novices. They measured the typicality judgment by asking how good the examples are and analyzed the factors that predict the typicality (goodness-of-the-examples) judgment; the potential factors considered were familiarity, central tendency (similarity to other trees), and ideals. In this study, height was presented as a positive ideal, while weediness was considered a negative one. The results revealed that ideals were the main predictor of typicality judgment for tree experts. However, for novices, familiarity determined the typicality of trees. Moreover, different experts showed systemic differences in the predictors of typicality (for the results, see Lynch et al., 2000, p. 45, Table 2). These findings indicate that different experts may hold different ideals for the same categories, leading to divergent typicality judgments. For instance, the attribute of height may be significant for landscapers but not for maintenance workers. These results demonstrate that ideals are important for determining how typical the given instances are, even in natural categories. Since ideals are instances that fulfill the designated function within a category, they can serve as a proxy to estimate the impact of "for what" information.

The second sort of evidence comes from experiments showing that knowledge of function affects categorization judgments. In one experiment (Lin & Murphy, 1997), subjects first learned about an artifact (named 'tuk') in a foreign country and were then asked to categorize various objects similar to a tuk. The subjects were divided into two groups: one group (Group A) was told that the tuk was for hunting, while another group (Group B) was told that it was a fertilizing tool. The two groups have entirely different stories about it, particularly its function. The tuk has four parts, but each part plays different roles for different functions. As a hunting tool, (Part 1) is a noose for the animal's head, pulling on (Part 4) is an apparatus for tightening the noose, (Part 3) is the handle, and (Part 2) is the hand guard to protect the hunter from animal bites and scratches. As a fertilizing tool, (Part 2) is a tank for the liquid fertilizer, (Part 4) is the outlet pipe, (Part 3) is the knob, and (Part 1) is the loop used to hang the tool (Fig. 1).

A crucial question is whether the difference in functional knowledge influences subjects' categorization. To test this question, the researchers created items that lacked one or more parts: one item lacked the triangular part in the middle (Consistent A), one item lacked the loop at the top (Consistent B), and another item lacked both (Control). Then, subjects were asked to judge whether each item was a tuk. Researchers found interesting effects of func-

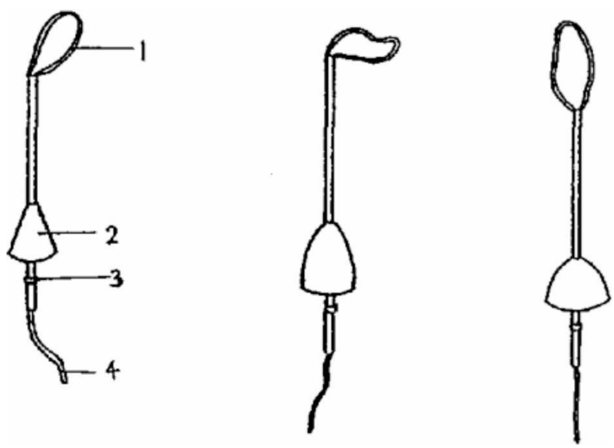

Fig. 1 Examples of learning instances from Lin and Murphy (1997)

tional information on the categorization judgment. The hunting group (those who learned the tuk was a hunting tool) did not categorize Consistent B (the item with the missing loop) as a tuk, but they judged that Consistent A (the item with the missing triangular part) was a tuk. In contrast, the fertilizer group (those who learned the tuk was a fertilizing tool) categorized Consistent B as a tuk but did not categorize Consistent A as a tuk. Although all subjects saw the same objects, they drew different conclusions depending on their knowledge of function.

By investigating the nature of concepts, psychologists have accumulated evidence demonstrating that ideals and functional information affect people's judgments of typicality and categorization (see also Lombrozo & Rehder, 2012). These experimental studies are sufficient to establish that functional information influences our cognitive processes, thereby establishing the psychological reality. People learn and use concepts with consideration of what the concepts are used for and why they have the concepts (Murphy, 2002). Therefore, the function of concepts is not determined on an ad hoc basis solely to account for rational conceptual changes and variations in history of science. Instead, the significance of functional information emerges from the very nature of concepts.

One might argue that it is too hasty to draw conclusions based on the empirical studies mentioned above. As I mentioned earlier, those were not conducted on a specific assumption of functional information (e.g., an etiological function in a specific sense, function as a metainformation). Thus, it would be fair to assert that these studies only demonstrate the existence and influence of "for what" information. My replies are two-folded. First, although the functional information utilized in the studies is not particularly etiological in the sense we proposed, it is still compatible with etiological interpretation. Moreover, by reading the function from the generalized etiological perspective, the effect of functional information on our cognition becomes more concretely appreciated. Second, the functional information can be properly regarded as a regulatory metainformation. The "for what" information contributes to the typicality judgment for the tree experts and determines whether a specific feature is essential or not. Therefore, the cognitive approach to concepts that treats the function of a concept as metainformation offers a plausible framework to interpret the empirical results. While acknowledging the limitations of the empirical studies, considering functional information as regulatory metainformation offers a viable explanation for the empirical findings.

7 Conclusion

The function of scientific concepts matters. While Brigandt deserves credit for emphasizing the significance of the epistemic goals pursued by a concept's use, his proposal to consider these goals as the third semantic component of concepts is problematic for two reasons. First, it remains unclear how these goals are characterized and what their status is. His proposal misplaced the functions of concepts as one of the semantic properties. Second, his semantic proposal is not well grounded. He introduced the function in order to account for the rationality of conceptual changes, failing to establish its (psychological) reality. The problems stem from the limitations of the semantic approach to scientific concepts. To address these limitations, I propose an alternative, cognitive approach, according to which concepts are information-complexes wherein functional information reveals the goals for which concepts are used. In this perspective, the function of scientific concepts, as defined by a generalized etiological notion of function, is regulatory meta-information rather than a part of the semantic content. Importantly, this notion of function has psychological reality, providing an independent ground for its incorporation.

In conclusion, the function of scientific concepts, as revealed by functional information within information-complexes, goes beyond the semantic content. By adopting a cognitive perspective and embracing a generalized etiological notion of function, we recognize its role as regulatory metainformation. Moreover, the psychological reality of this function offers a solid foundation for its inclusion in the study of scientific concepts.

Declarations

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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