Metascience
DOI 10.1007/s11016-012-9642-9

BOOK SYMPOSIUM

# The ICE-theory of technical functions

## Houkes, Wybo and Vermaas, Pieter E.: Technical functions: On the use and design of artefacts. Dordrecht: Springer, 2010, viii+175pp, €99.95 HB

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## Erik Weber

Because this is the first contribution to the book symposium on *Technical Functions*, I want to give the readers a general idea of the nature of the book. The aim of the book is normative rather than descriptive:

> This choice means that we approach both artefacts and the actions in which they play a role largely from a *normative* rather than a descriptive perspective. We do not offer a theory about how people actually use or design artefacts, or how they in fact describe them in functional terms; instead we seek to provide

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Published online: 04 April 2012

a framework for evaluating some aspects of these activities, and we theorise about rational and proper artefact use, and about justifiable function ascriptions (4).

The authors review three function theories for technical artefacts: the intentional (I) theory (Neander, Bigelow and Pargetter, McLaughlin, Searle), the causal-role (C) theory (Cummins) and the evolutionist (E) theory (Millikan). After exposing the weaknesses of these accounts, Houkes and Vermaas propose their own theory, which is called the ICE-theory because it combines the insights from the three basic theories. Function ascriptions to artefacts are analysed against the background of artefact use and design. The use of an artefact is captured as the carrying out of a use plan for the artefact. Design is seen as primarily the development of new use plans for artefacts. Another important feature is that the theory is agent oriented rather than property oriented: Their theory takes the form of a theory of *justifiable function ascriptions* by human agents rather than a theory that identifies functions as properties of artefacts.

The core of the theory consists in two definitions of justifiable function ascriptions (one for designers or justifiers and one for passive users; see 88–89). These definitions can be merged into one definition. At a symposium during the 3rd Conference of the European Philosophy of Science Association (EPSA11), in which the book was discussed, Houkes and Vermaas proposed the following general definition (which does not distinguish between the two types of agents):

An agent *a* justifiably ascribes the physicochemical capacity to $\phi$ as a function to an item *x*, relative to a use plan *up* for *x* and relative to an account *A*, iff:

I *a* believes that *x* has the capacity to $\phi$;
*a* believes that *up* leads to its goals due to, in part, *x*'s capacity to $\phi$;
C *a* can on the basis of *A* justify these beliefs; and
E *a* communicated *up* and testified these beliefs to other agents, or *a* received *up* and testimony that the designer *d* has these beliefs.

I will use this definition in my comments below.

Houkes and Vermaas put forward four desiderata for a theory of technical functions:
*The proper-accidental desideratum*:
A theory of artefacts should allow that artefacts have a limited number of enduring proper functions as well as more transient functions.
*The malfunctioning desideratum*:
A theory of artefacts should introduce a concept of proper function that allows malfunctioning.
*The support desideratum*:
A theory of artefacts should require that there exists a measure of support for ascribing a function to an artefact, even if the artefact is dysfunctional or if it has a function only transiently.
*The innovation desideratum*:
A theory of artefacts should be able to ascribe intuitively correct functions to innovative artefacts (5)

The clauses I, C and E in the definition ensure that the *support* desideratum is satisfied. I cannot go into the three other desiderata for lack of space. Instead, I want to propose a fifth desideratum:

*The utility desideratum*:
A theory of artefact functions should tell us why and under which conditions function ascriptions are useful.

Let me clarify this. I think that Houkes and Vermaas have developed an adequate theory of when function ascriptions are justified and how they have to be justified. However, such a theory is of no use for agents if it is not supplemented with a theory of when and why it *makes sense* to make function ascriptions. In other words, we need a theory of when and why function talk is useful and/or to be preferred relative to other (non-functional) modes of speech. So I think there is something missing if the ICE-theory is to be a *complete* theory of function ascriptions: In its current form, it is a theory of the *justifiability* of function ascriptions. However, there is very important further work to be done: reflecting on the usefulness of function ascriptions. In the rest of this contribution I want to do a tiny bit of that work. I will concentrate mainly on explanations because that is my area of specialization. So my main purpose will be to investigate why and under which conditions it is useful to develop *functional* explanations (explanations that use function ascriptions) as opposed to other types of explanation. In this contribution, I will first discuss cases in which—in my view—function ascriptions have a mere heuristic value: They lead the way to a proper explanation, but the proper explanation does not contain function ascriptions. Then I discuss a case in which function ascriptions have a *substantial* role. In these cases one cannot remove the function ascriptions without ending up with an inferior explanation. I end my contribution with some questions to Houkes and Vermaas.

The first type of cases we consider are questions of the following form:

(1) Why was artefact $x$ produced?

Functional explanations we can give to answer such questions have the following format:

(2) Artefact $x$ was produced because there was a designer $d$ who justifiably ascribed the physicochemical capacity $\phi$ as a function to $x$.

Let us consider an example:

(3) Why was the computer mouse produced?

A possible answer is:

(4) The computer mouse was produced because there was a designer $d$ who justifiably ascribed the capacity to indicate X–Y positions on computer screens as a function to the computer mouse.

According to the ICE-theory, this explanation is shorthand for:

(5) The computer mouse was produced because there was a designer $d$ who had a use plan *up* for it and an account A. $d$ believed (1) that the computer mouse has

the capacity to indicate X–Y positions on the computer screens and (2) that *up* leads to its goals due to, in part, this capacity. *d* could on the basis of *A* justify these beliefs. *d* communicated *up* and testified these beliefs to other agents.

This explanation naturally leads to several follow-up questions: Who was the designer *d*? What was the use plan he had in mind? What was the goal? To whom were the beliefs communicated? For instance, the goal may have been to speed up computer processing by feeding commands into the CPU without touching the keyboard. And the people to which the beliefs were communicated may include production managers, financial and marketing managers and the general manager of the enterprise in which the designer is working.

In my view, a satisfactory explanation of the fact that the computer mouse was produced should include the details referred to in these additional questions. The information about the designer can be included without giving up functional talk:

(6) The computer mouse was produced because Douglas Engelbart justifiably ascribed the capacity to indicate X–Y positions on computer screens as a function to the computer mouse.

However, the rest of the information cannot be communicated by means of function talk; from explanation (6), we cannot derive what Engelbart's use plan was, what his account was, to whom he talked, etc. So this explanation has a *heuristic* role: It is a first and important step towards a complete and satisfactory explanation. And, more importantly, this complete and satisfactory explanation does not use function talk: We have to remove the notion of function in order to fill in other, more detailed information: his use plan, goals, communication partners, etc.

This point can be generalized: Explanations that fit scheme (2) are only a first step, even if we fill in the name of the designer(s) and fill in the capacity as we did in (6). The complete explanation is an implementation of the following scheme:

(7) Artefact x was produced because there was a designer *d* who had a use plan *up* for it and an account A. *d* believed (1) that *x* has the capacity to $\phi$; (2) that *up* leads to its goals due to, in part, this capacity. *d* could on the basis of *A* justifies these beliefs. *d* communicated *up* and testified these beliefs to other agents.

In this scheme, the word 'function' does not occur. So in the final explanation, there are no function ascriptions.

The situation described till now was one where functional explanations are not the optimal ones: There is a non-functional alternative that is better. I think that there are also contexts where the opposite is true: situations where dropping the function ascription leads to an inferior explanation. I will now present an example of such a context: diagnostic reasoning.

Consider an artefact that does not have a capacity which we expect it to have. In such situations, explanation-seeking questions of the following format arise:

(8) Why does artefact *x* not have the expected capacity $\phi$?

For instance, Why does my newly bought computer mouse not have the expected capacity to indicate X–Y positions on my computer screen? Or, Why does my stamping machine not produce stamps as expected? These questions are contrastive: They contrast the real situation with the ideal situation that we expected and hoped for. I think function ascriptions have a substantial role here. For an elaborate example and argument, see (Weber and Preester 2005). Here I can only introduce the two main ideas. First, explanations that answer contrastive questions usually have a different form than explanations which answer questions about plain (non-contrastive) facts. Second, this rule also holds in the case of capacities: explaining why an artefact has a capacity can be done without using function ascriptions, but in order to explain why it does not have a capacity it is supposed to have, function ascriptions are the best tool.

Peter Lipton (1993, 53) gave a nice example to illustrate the first point:

> Suppose that my car is belching thick black smoke. Wishing to correct the situation, I naturally ask why this is happening. Now imagine that God (or perhaps an evil genius) presents me with a full deductive-nomological explanation of the smoke. This may not be of much help. The problem is that many of the causes of the smoke are also the causes of the car's normal operation. Were I to eliminate one of these, I might only succeed in making the engine inoperable. By contrast, an explanation of why the car is smoking rather than running normally is far more likely to meet my diagnostic needs.

In Lipton's view (which I share), the explanation of the contrast should pick out only the causes that make a difference and hence cannot have the form of an argument as required by the covering law model. The explanation of the contrast (why smoke rather than normal functioning) has a format that differs from the explanation of the plain fact (the presence of the smoke).

The second point can be clarified by means of the main idea of complex-system mechanism: One can explain the behaviour (e.g. the capacity) of a complex system (such as an artefact) by describing the entities of which the system is composed, the activities of those entities and their organization (see Machamer et al. 2000). In explanations of such plain facts, we do not need function ascriptions. However, if we explain why an artefact does not behave as expected, a full mechanistic story is as much an overkill as a complete deductive-nomological explanation in Lipton's example. What we need is a way to pinpoint what has gone wrong. This can be done by a function ascription, more precisely be claiming that a component *malfunctions*. The functional explanation is the most efficient way to find out and communicate what went wrong so that the artefact can be repaired. Information about the organization and about the other entities and their behaviour should be left out.

The reflections I made in this contribution quite naturally lead to some questions I would like to pose to the authors. First, I would like to know whether they agree that a fifth—utility—desideratum must be added in order to have a complete philosophical theory of technical functions. Second, whether they agree that function ascriptions have a mere heuristic role in some contexts. Third, whether they agree that function ascriptions have a substantial role in other contexts. Finally—and most importantly—I would like to know what they think about the role of function ascriptions outside explanatory contexts, for example, in the contexts of designing an artefact rather than explaining its presence or its properties after it has been created. Do function ascriptions have a substantial role there or a merely heuristic one?

**Thomas A. C. Reydon**

In *Technical Functions*, Wybo Houkes and Pieter Vermaas aim to develop a philosophical account of how designers, makers and users of artefacts ascribe functions to artefacts and their parts. The scope of the book, thus, is more restricted than most philosophical work on the topic of functions. First, the authors do not aim to develop an account of the *nature* of functions (i.e. of what it means for things to *have* functions), but only of function *ascriptions* (i.e. of the criteria of legitimate function ascription to items by people; e.g., 48, 134). On their view, items can be said to have their functions at most relative to the beliefs of agents (134). Thus, the account they articulate and elaborate in the book, ICE-theory, 'falls squarely in the intentionalist tradition' (3), according to which 'the intentions of agents fix the functions of technical artefacts' (2). This aspect of the theory—the 'I' in 'ICE'—sits well with the specific context under consideration: The theory is about designers, makers and users who ascribe functions to items.

Furthermore, Houkes and Vermaas do not consider functions in general, but only in the specific contexts of technology, engineering and everyday artefact use (1–2). However, despite this explicit limitation of the domain of applicability of their work, Houkes and Vermaas do consider a possible extension of their ideas to other domains in which functions play a role. This is the aspect of the book on which I shall focus in the present review.

While the largest part of the book is devoted to the elaboration and articulation of ICE-theory for the case of technical artefacts, the book also touches upon a much more ambitious project. In chapter 6, Houkes and Vermaas explore whether ICE-theory could also be applied in other cases, most importantly for function ascriptions to naturally occurring entities. This is an important question: Function ascriptions commonly occur in various special sciences, most prominently in biology, and one would expect that the notions of 'function' that occur in various domains have something in common. That is, when a designer of an artefact ascribes a function to a part of that artefact, it seems that he or she to a certain extent is doing the same as a biologist who studies an organism and ascribes a function to one of its parts. A desideratum for accounts of function ascriptions thus seems to be that they should cover all cases in which functions are ascribed to entities—although it should be noted that there is no a priori reason to assume that a designer and a biologist are actually talking about the same thing when they talk about functions!

There are reasons to doubt the applicability of ICE-theory outside the domains for which it was originally developed. For one, ICE-theory is an action-theoretical theory, attuned to function ascriptions in contexts in which people design and use artefacts for particular purposes. On ICE-theory, function ascriptions are conceptualized in terms of use plans, that is, plans that specify how artefacts are to be used in such a way that their various capacities contribute to realizing particular goals that their designers or users envisage. Accordingly, ‘the central feature of technical artefacts [is] their intimate connection to teleology’ (1). But intentionality and teleology are highly problematic notions in many special sciences, most importantly biology, as Houkes and Vermaas acknowledge. Biological items should not be thought of as intentionally designed or used by the organisms that possess them. Nevertheless, biologists commonly ascribe functions to organismal traits and structures, and philosophers of biology have elaborated several accounts of these practices (for an overview, see Wouters 2003; 2005). One question, thus, is whether an intentionality- or teleology-oriented account of function ascriptions such as ICE-theory could at all be applicable in such contexts and, furthermore, why such an account should be expected to perform better than the already available competitors.

An additional problem can occur because ICE-theory is intended as an account of function *ascriptions* (48, 134). But in many special sciences, including biology, the question is not on what grounds it would be correct for us to ascribe functions to particular items, but how the functionality of particular items is to be understood. This is, however, well beyond the scope of ICE-theory. Thus, even if ICE-theory would be applicable outside its proper domain, it would still do less work than competitor accounts that move beyond mere ascriptions of functions to specifying the nature of functions that items can be said to have by themselves.

Houkes and Vermaas suggest two ways in which the above mentioned problems might be avoided, but leave much of the required research for other investigators to carry out, stating that more ‘[d]etailed research is needed to examine whether the theory can stand its ground as an immigrant in these wider and more crowded domains’ (12). The above mentioned problems occur when ICE-theory is taken as a package deal—i.e., in the precise form in which it was developed for its original domain—and then applied literally to cases of function ascription in other domains. But this, Houkes and Vermaas suggest, one should not do. Instead, one might conceive of functions in other domains *as if* they were technical functions (in the manner of Dennett’s intentional stance) and apply ICE-theory to the intentional analogues of biological functions. But Houkes and Vermaas (128–131) reject this approach because it fails to do justice to one of the core elements of ICE-theory, namely the fact that functions are ascribed on the basis of use plans that are formulated by designers and users of items and communicated to other (potential) users of these items (see Weber, this symposium). Even if one agrees on a suitable notion of ‘as-if design’, it seems impossible to identify the users of biological items to whom use plans are communicated. One might perhaps think of organisms as the users of their traits (e.g. Matthen 1997), but as Houkes and Vermaas point out, organisms and the hypothetical ‘as-if designer’ of their organs do not stand in any communicative relation, such that an application of ICE-theory in ‘as-if mode’ will fail.

Houkes and Vermaas thus turn to a second, ‘more daring’ route (117) which involves constructing modified versions of ICE-theory for application elsewhere. As Houkes and Vermaas point out (131), this might be done in two ways. One might try to come up with ad hoc ‘ICE-like’ theories for different domains—one version tailor-made for biological functions (‘b-ICE-theory’, 131), another version tailor-made for another domain, etc. Or one might try to generalize ICE-theory in such a way that the generalized theory ('g-ICE-theory', 131) constitutes an overarching theoretical structure that is concretized in different ways for application in different domains. Could this second route work? I want to argue that this does not constitute a feasible way out either. Let me focus on biological functions and b-ICE-theory to make my argument.

The construction of a b-ICE-theory for the biological domain proceeds by way of translating the key concepts of ICE-theory into suitable analogues for the biological domain, while keeping the overall structure of the original theory intact (132). Some of the relevant key concepts are the following: 'design', 'use', 'use plan', 'account' and 'communication chain'. The concepts of 'design', 'use' and 'use plan' feature in the context of function *identification*. The function of an item follows from the use plan for the item that is formulated by a designer—or user, as later users can assume the role of 'redesigners' of items (Houkes 2008)—and that specifies which of the item's capacities are supposed to contribute to the realization of an envisaged goal. In this sense, an item's function is dependent on the goal that the designer has in mind and the use plan in turn identifies the function of the item. The concept of 'account' features in the context of the *explanation* of functions. As Houkes and Vermaas explain (e.g. 80), for someone to be able to ascribe a function to an item, they need to be able to justify their belief that the item can indeed be used to realize the envisaged goal. Such a justification must rest on, among other things, a physicochemical account that specifies how the various capacities of the item can feature in the realization of the goal specified in the use plan by, for example, specifying relevant causal relations, a mechanistic model, etc.

Finally, the concept of 'communication chain' (81–83) is related to the action-theoretical basis of ICE-theory. Function ascriptions need to be grounded in a sufficient epistemic basis (that is, the use plan and the supporting account). A designer can thus ascribe a function to an item on the basis of the use plan that he or she devised him/herself plus the physicochemical account that supports this use plan. Later users of the item can justifiably ascribe the same function to the item only if they have largely the same epistemic basis, that is, if they know both the use plan and (part of) the supporting account. Of course, users don't need to know the whole use plan and physicochemical story in detail, but they do need to possess at least a minimal epistemic basis for this function ascription—That is, they need to have at least a minimal level of knowledge of the use plan that identifies the item's function and of the underlying account. Thus, some of the necessary knowledge must be communicated to them, for example by means of testimony (e.g. 100): 'From the perspective of a user who looks back towards the structure of the use plan, this history [of communication] looks like a communication chain of agents who have informed one another about the plans and who provided or passed on support for each other's effectiveness beliefs' (81).

The translation of these key concepts proceeds by constructing analogous concepts for the biological domain, thus involving only weak similarities between the two sides. (After all, b-ICE-theory is supposed to be an 'ICE-like' theory, not a literal transposition to the biological domain.) While at first sight, the straightforward option seems to be to take natural selection and heredity as analogues of technical design and a communication chain, respectively, Houkes and Vermaas reject this option because the concepts of 'design', 'use' and 'communication chain' would fail to 'define the roles taken by agents when they ascribe functions to biological items' (132). What b-ICE-theory should account for is how biologists ascribe functions to the items they study, in the same way as ICE-theory should account for how designers, makers and users ascribe functions to the items they handle. But since biologists as agents do not enter into the processes of natural selection and heredity, taking natural selection and heredity as the analogues of design and communication clearly will not work.

Houkes and Vermaas (133–134) instead propose to take discovery as the analogue for design and communication between researchers as the analogue for the communication chain between designers and users. The idea is that in the same way as designers identify the functions of items on the basis of use plans that they devised and supporting physicochemical accounts, biologists identify the functions of biological items on the basis of analyses that describe the role of the items in the context of the systems (organism, ecosystem, etc.) in which they occur and underlying physicochemical accounts that specify how the item's capacities contribute to the survival of the systems. In the same way as designers communicate use plans to the items' users, biologists communicate their analyses to the scientific community in their publications. On ICE-theory, the communication chain starts with the designer (132), while on b-ICE-theory the communication chain starts with the discoverer of a biological function and allows other researchers to ascribe the same function to items of the same kind. While at first sight this may seem a plausible parallel, I want to argue that the parallel is too weak to result in a feasible account of biological functions. At least three problems can be mentioned.

The first problem can be summarized by the slogan 'the designer is always right'. It originates in the fact that ICE-theory in fact is more than just an account of function ascriptions. On ICE-theory, designers and users do more than just to ascribe functions to items. What they do, I would suggest, is to *impose* functions onto items—they *cause* items to *have* particular functions. When a designer devises a use plan for an item, he or she sets a goal and determines which function this item should perform. The physicochemical account underlying the use plan may be correct or flawed, in the former case leading to a successful imposition of a function onto the item, in the latter case leading to an unsuccessful one. In both cases, we have an agent's action that (successfully or not) causes an item to have a particular property—its proper function. The designer's use plan fixes *the* function of the artefact for the relevant social community of people who can be confronted with the artefact. If a second good use plan comes into play (devised by a user acting as a 'redesigner'), this specifies a second proper function of the item that stands next to the first proper function and so on. Thus, contrary to Houkes and Vermaas' claim (134), ICE-theory does seem to allow for items *having* functions independently of the beliefs of those people who are confronted with the item (except, of course, the designer and later redesigners). It is in this sense that the designer is always right: He or she is the authority who determines the item's function.

This situation is different for biology. The biologist's research questions when confronted with an organism's trait is, among other things, what caused its presence and its spread throughout the population, what role the trait plays in the context of the system that possesses it, or how having or lacking the trait plays a role in selection processes. For artefacts, one may ask similar questions but there are final authorities (the first designer and a couple of later redesigners) that determine what are the right answers (even if in practice it may not be possible to consult them). In the case of biological items, however, there are no such authorities and the answer to the question what the function of a particular item is depends on the research context of the biologist. Despite occasional talk of proper biological functions, there is no ultimate answer to the question, 'What is *the* function of trait T?' What one identifies as the proper function of an item is dependent on one's focus of research (selection history, comparative anatomy, etc.)—which is why many biologists and philosophers of biology today are pluralists with respect to biological functions.

The second problem pertains to *retrospective function ascription*. Consider the case of something that looks like an artefact (call it *X*) that with respect to its structure is entirely the same as present-day artefacts of a particular kind *K*, but existed at a time well before the invention *K*s. Because on ICE-theory function ascriptions must be supported by a communication chain that starts with the first designer of artefacts of the *K*, item *X* cannot be ascribed the function of *K*s and cannot even be considered a member of artefact-kind *K*, as it existed well before anyone first thought of making *K*s. For biological items, however, such a restriction wouldn't make much sense. Biologists routinely hypothesize about the functions of traits of organisms long dead and gone, and biological items can have functions even if no researcher has yet studied them. This problem, too, highlights the role of designers in fixing the functions of artefacts: Because the designer is always right, one cannot ascribe a function to an item that existed at a time before a designer has come into play.

Related to these problems for b-ICE-theory is a third problem that I want to point out briefly here: a *kind allocation problem*. On the basis of use plans that are communicated from the original designer (and later 'redesigners') to users and other people confronted with artefacts of the kind, artefacts can be unequivocally allocated to kinds. Something *is* an ashtray if someone devised it as an ashtray or remade it on the basis of someone else's concept of what it is to be an ashtray. (Cf. Amie Thomasson's point that making an artefact of kind *K* must involve having a 'substantive concept of the nature of *K*s that largely matches that of some group of prior makers of *K*s'— see Thomasson 2003, 600.) Again, this problem relates to the function-fixing role of designers and 'redesigners' in ICE-theory. While the allocation of artefacts to kinds is fixed to an important degree by the artefacts' functions which in turn are fixed by the intentions of designers and 'redesigners', in biology the allocation of items to functional kinds is more flexible. In the context of one research programme, it might be called for to allocate an item to one particular functional kind, but in the context of another research programme a different functional classification may be more appropriate.

All three problems can be seen as manifestations of a crucial epistemic difference between the cases of artefacts and biological items. The action-theoretical element of ICE-theory reflects the authoritative role of designers and 'redesigners', making the theory appropriate for function ascriptions in technology, engineering and everyday artefact use. But in biology such an authoritative role is lacking, such that b-ICE-theory (which as an 'ICE-like' theory must have an action-theoretical basis too) does not fit function ascriptions to biological items. Houkes and Vermaas in my view have presented an excellent account of how functions are ascribed to technical artefacts. However, I believe the scope of applicability of their account will remain confined to entities of this kind. The three problems for b-ICE-theory, highlighted above, show that some of the key concepts in ICE-theory run into difficulties when they are translated into analogues for the biological domain. When it comes to biological functions, we have to admit that the epistemic practice of discovering (or better: hypothesizing about) the functions of biological items is fundamentally different from the epistemic situation in which designers, engineers and users of artefacts find themselves. And this should make us cautious when talking about functions in a general sense: The aim of devising a philosophical theory of functions that covers all function talk—in different contexts of biology, in technology and engineering, and in others contexts—may well be misguided.

## Mieke Boon

Wybo Houkes and Pieter Vermaas have developed a theory of technical functions that focuses on the attribution of technical functions to artefacts. They aim at a non-essentialist account of technical functions by reference to use plans. 'Use plan' means a more or less standardized way of manipulating objects in order to realize a practical goal, which is the business not only of designers but also of users. Houkes and Vermaas develop their theory by starting from the idea that artefact-using can be reconstructed as the execution of a use plan of those artefacts. In their account, they incorporate elements of existing intentional, causal-role and evolutionist function theories, which is why they call it the ICE-theory of technical functions. The theory can be applied for evaluating the use of artefacts because it enables us to *reconstruct* technical functions by reconstructing the use plan of those artefacts. In other words, the ICE-theory allows for evaluative purposes regarding the justifiable ascription of functions to artefacts relative to their use plans. In general, I am sympathetic about the ICE-theory. Also, I value their methodological approach, in particular because they explicitly articulate the desiderata their theory must meet and because the authors are very explicit about the scope of their theory.

Houkes and Vermaas are explicit about the fact that their theory has a limited scope: It is a theory about justifiable function ascription to artefacts. Nevertheless, the authors suggest that their theory is relevant to the design of artefacts, which is a claim I doubt. My own ideas about technical functions—or, technological functions as I call them—have been formed through the perspective of the engineering sciences. The engineering sciences are scientific research practices in the context of technological applications. They aim at *newly creating and improving technological functions* that are physically embodied and exerted through technological artefacts such as (assemblies of) materials, processes, apparatus and instruments (Boon 2011).

Against this background, my difficulty with Houkes and Vermaas' ICE-theory of technical functions is that it only accounts for function ascription to artefacts with hindsight. It does not clarify much about the interrelated activities of scientific research, design and development by means of which technological artefacts with certain intended technical functions come about. Put differently, I don't see how their account might accommodate philosophical accounts of creating and improving technological artefacts.

In part, this shortcoming of the ICE-theory may be attributed to the choice of the authors to take philosophical accounts of functions in biology as their starting point, which in my view, has confined their approach and the possible outcomes unfavourably. Hence, whereas Reydon (in his contribution to this symposium) rejects the suggestion of Houkes and Vermaas that their ICE-theory could also be applied for function ascriptions in other domains, in particular, biology, I argue that their ICE-theory for function attribution to artefacts has been modelled too much after ideas about biological functions, thus ignoring the contribution of the design and development process. This appears from the fact that—in spite of talk about design—Houkes and Vermaas seem to take technological artefacts as somehow pre-given rather than objects that are being designed and developed in view of certain intended technical functions. This take on the matter is similar to how in accounts of biological functions species are taken as pre-given rather than designed. As a consequence—and also, because Houkes and Vermaas do not aim at an account of what it means for things to *have* functions, that is, a theory of the *nature* of functions—the seemingly most significant question that arises due to this approach is how the attribution of a technical function to the artefact can be justified.

Reydon (in his contribution to this symposium) is especially critical about the role of the designer in applying the ICE-theory to biology. In his critique, he assumes that the biologist would have the role of the designer. Conversely, in my view, the ICE-theory fits to a Deist-teleological view on biology, in which the designs of different species spring from the mind of the designer-God. Applying the ICE-schema to biological functions would then yield:

The designer-God, *D*, and Adam, *a*, justifiably ascribe the physicochemical capacity to $\phi$ (e.g. the capacity to fly) as a function (e.g. flying) to a part of the body of a species, *x*, relative to a use plan *up* for *x* and relative to an account A, *iff*:

I The designer-God, *D*, and Adam, *a*, believe that a part of the body of a species, *x* (e.g. wings), has the capacity to $\phi$ (e.g. to fly); *D* and *a* believe that *up* (e.g. birds using wings in such and such a way) leads to its goals (e.g. transporting itself from positions A to B, catching a prey, or protecting itself against predators) due to, in part, *x*'s capacity to $\phi$ (e.g. due to, in part, wings' capacity to fly).

C *D* and *a* can on the basis of A (e.g. that the designer-God has created wings such that they can lift a bird by means of thermals) justify these beliefs.

E Adam communicated *up* (e.g. birds using wings in such and such a way) and testified these beliefs to other humans; or Adam received *up* and testimony that the designer-God has these beliefs.

On this account, concepts of a specific function, as well as how this function is physically embodied and exerted, spring from the mind of the designer, *D*. Subsequently, the designer, D, and other rational beings, *a*, decide whether the materialized artefact indeed has the envisioned function, which involves that all sentences of the ICE-theory apply. Therefore, the three theories of functions gathered in the ICE-theory apply in the following way: (I.) The intentions of the designer-God have fixed the function of, say, wings, which is in accordance with *intentionalist theories of function*. (C.) Also, the function of (parts of the body of) a species *x* (e.g. wings) is related to the causal role that *x* has in the whole system (e.g. birds can fly), because an explanation of why birds can fly has been given in terms of why wings enable birds to fly (A)—which agrees to *causal-role theories of functions*. (E.) Finally, the physicochemical capacity to $\phi$ (e.g. the capacity $\phi$ to fly) counts as an evolutionist function of a species (e.g. birds) because that capacity contributed positively to their reproduction. Applying Houkes and Vermaas' reading of *evolutionist function theories* to my Deist-teleological interpretation of the ICE-theory points out that the designer-God believed that the capacity to fly contributes positively to the reproduction of birds and that Adam has received this understanding of the function of wings from the designer-God. In sum, the ICE-theory enables a systematic account of how Adam justly attributed functions to the species that God showed him and asked to give names.

Clearly, my interpretation unjustly ignores several features the ICE-theory has and which account for the fact that human designers are neither omniscient nor omnipotent and possibly not omnibenevolent either. These limitations are responsible for occurrences in which designed artefacts are not useful (e.g. because the bird has wings but there are no thermals in nature) or not completely successful (e.g. because the aerodynamics of the wings are suboptimal) or their functioning may be physically restricted (e.g. because there are only thermals in the early morning). Nonetheless, the other side of being a human designer is their ability to find creative solutions and new applications. Houkes and Vermaas call these four phenomena *use versatility*, *possible lack of success*, *physical restrictions* and *innovation*. These phenomena are reflected in the four desiderata they propose for the theory of technical functions (5). These desiderata must account for the fact that: (a) artefacts have a limited number of enduring proper functions as well as more transient accidental functions (*the proper-accidental desideratum*); (b) our ideas about the proper functioning of an artefact may disagree with its actual functioning, which enables us also to decide on its malfunctioning (*the malfunctioning desideratum*); (c) there exists a measure of support for ascribing a function to an artefact, even if the artefact is dysfunctional or if it has a function only transiently (*the support desideratum*); and (d) designers and users have the ability to ascribe intuitively correct functions to innovative artefacts (*the innovation desideratum*).

However, in spite of these features of the ICE-theory, the issue remains that functions usually are not *attributed* to technological artefacts afterwards. In real practice, conceptions of technical functions, and the artefacts embodying these functions, result from an often troublesome process of scientific research, design and development carried out by scientific researchers, engineers and users. Hence, the concept of a technical function and the design of the technological artefact that supposedly will manifest it usually do not spring spontaneously from their minds. Therefore, the ICE-theory seems to be very restricted in the sense that it only offers a conceptual tool for evaluating whether an artefact has a designated function—that is, to assess whether someone (e.g. the designer or the seller) justly claims that this artefact has such and such a function.

In the remainder of my contribution, I aim to explore how to go about developing an account of technological functions that also accommodates the design and development of technological artefacts for performing desired functions. I will propose that at least three notions are needed for developing this account, namely *conceptions* of technological functions, *manifestations* of technological functions, and *physical phenomena* (e.g. substances, properties or processes) that *produce* (or are held responsible for) the functioning or malfunctioning of a technological artefact.

The roles these notions play in accounting for a technological function can be made somewhat more concrete by means of a very simple example, for instance, how researchers and engineers think about paint. The desired technological function(s) of paint includes properties such as protecting a surface, workability in its application, durability and aesthetic qualities. Hence, our *conception* of the technological function of paint involves these kinds of qualities. The *manifestations* of the technological function(s) involve perceivable, measurable and/or quantifiable properties of paint such as its colour, its viscosity and its fastness of drying, its adherence to a surface, its smoothness, its shininess, its hardness and the stability of these properties. Examples of *manifestations of technological dysfunctions* of paint are properties such as the tendency to maintain ripples; the increase in its viscosity when applied at higher temperatures; the tendency to capture air bubbles; the toxicity of the solvent; its poor scratch resistance; the formation of cracks in hardened paint; loss of colour; and the tendency to turn yellowish under the influence of sunlight. A common sense kind of approach to the improvement of the technological functioning would be trial-and-error interventions with the *technological artefact* at hand, for instance, by systematically testing the effects of different kinds of solvents or pigments or filling materials in the case of paint. Sometimes this is considered as a typical engineering approach. Different from, and often additional to the trial-and-error approach, the *engineering sciences* focus on creating and intervening with the physical *phenomena* that produce the proper and/or improper functioning of technological artefacts. Examples of such phenomena are evaporation of solvent; molecules responsible for the colour of paint; degradation of colour molecules under the influence of heat or light; chemical or physical properties of pigments; and properties such as viscosity, diffusivity, hydrophobicity and surface tension of the solvent and polymers. The role of such physical phenomena is particularly important for understanding the contribution of the engineering sciences to the design and development of technological artefacts.

Scientific research that concerns the technological functioning of technological artefacts aims at finding ways for *improving* their functioning. Improving the technological functioning of paint may involve reducing the degeneration by sunlight of the pigments or the varnish polymers. Other examples of improving technological functions are enhancing the energy efficiency of engines; preventing the production of side products of chemical processes; and improving the mechanical properties of biodegradable fibres used in medicine. Additionally, scientific research aims at *creating* technological functions that do not exist as yet. Examples are an instrument that measures toxic levels of compound X in air; a membrane that separates pollutant P from waste-water Z; a molecule that converts sunlight to electrical energy; a material that is superconductive at relatively high temperatures; and a chemical process that exclusively produces one of the isomeric forms of a drug that has chemical composition M.

This brief example illustrates that technological artefacts—i.e., (assemblies of) materials, processes, apparatus and instruments—contain and/or generate physical phenomena that produce the (mal)functioning of these devices that we perceive or measure, that is, the manifestations of technological (mal)functioning. For a technological artefact to perform its desired technological function(s), researchers and engineers aim at producing the properties that are manifestations of its proper functioning and prevent or change the occurrence of those that are manifestations of its malfunctioning. The engineering sciences usually translate technological problems (e.g. the problem of how to *create* or *improve* a technological function) into scientific questions by conceiving of the (mal)functioning of a technological artefact in terms of the physical phenomena held responsible for its (mal)functioning (or, more precisely, the manifestations thereof). These phenomena then become subject of scientific research, which, besides other things, aims at knowledge that enables thinking about possibilities to create, reproduce, prevent, control, improve or otherwise intervene with these phenomena by means of technological interventions and artefacts.

I propose that in research and design contexts *conceptualizing* improvable or newly makeable technological functions involves sensibly discerning and putting together distinct kinds of knowledge, which I will briefly outline (also see Boon forthcoming). Conceptualizing technological functions may commence with articulating a *problem* that puts forward the practical purpose of a technological function, such as ‘worldwide depletion of fossil fuels’ or ‘water pollution’ or ‘UV light effected degradation of polymers’. Additionally, more or less abstract technological ideas on the type of *solution* involve conceptions of types of technological artefacts that perform relevant technological functions. Examples are ‘solar cells for producing electrical energy’, ‘ultrathin conductive layers in solar cells for reducing energy-loss of striking sunlight’, ‘membranes for physicochemical removal of toxic metals’, ‘additives that prevent the formation of free radicals’, ‘UV light reflecting nanoparticles in paint’, and ‘biologically functioning membranes for producing metal-ion-pumps’. Pointing out these kinds of possible solutions require technological, empirical and/or theoretical knowledge of how diverse technological artefacts function. Usually this involves empirical, technological and theoretical knowledge about the physical phenomena that may produce a specific (mal)function. Examples are knowing that membranes are capable of separating molecules from water and understanding how their specificity for certain types of molecules is attained, but also knowing that membranes easily get clogged in concrete technological applications; and knowing that nanoparticles have the capacity of reflecting UV light, and understanding how they do that, but also, knowing that nanoparticles may be toxic. Furthermore, conceptualizing *new* technological functions may draw on knowledge of phenomena that, considered from a theoretical perspective, may be utilized for performing a desirable function. An example is 'artificial photosynthesis' for the production of electricity or fuels (e.g. Pandit et al. 2006). Conceptualizing these kinds of technological functions involves the idea of 'technologically mimicking' parts of the natural photosynthesis. The conception of this technological function can be developed by thinking about ways of technologically *copying* parts of biochemical pathways through a technological device; in other cases, it involves the mere *conceptual use* of certain principles in terms of which scientists understand the functioning of technological or natural systems. An example of a principle devised for such conceptual use is 'that light is harvested by means of light-harvesting molecules in biochemical pathways of plants or algae' (e.g. Savolainen et al. 2008).

Why are the three notions proposed here—i.e., conceptions *of*, manifestations *of* and physical phenomena *for* technological functions—better suited as a starting point for developing an account of technical functions than existing I, C and E theories of functions that where originally developed in the context biology? Firstly, as has been sketched above, the three notions point at important features of the development of technological artefacts in research and design practices. Secondly, the given examples make plausible that the notion of *conceptualizing* technological function is crucial for explaining how technological artefacts are designed and developed. The conception of a technological function entails the different kinds of knowledge. Elsewhere, I suggest that this so-called epistemic content of the concept of technological functions enables thinking about improving or creating them, which implies that concepts function as 'epistemic tools' (see Boon forthcoming). In short, the formation of concepts of technological functions usually starts from thinking about possibilities of improving existing functions or creating new ones. It involves the use of relevant *empirical, technological and theoretical knowledge* about technological *problems*, existing *artefacts* and *functions*, and about physical *phenomena* that, on the one hand, are *generated by natural objects and/or technological artefacts*, and on the other hand, *produce the manifestations of their (mal)functioning*. Hence, resulting conceptions of technological functions consist of assemblies of heterogeneous bits of knowledge relevant for thinking about the actual technological production of these functions (i.e. producing them by means of artefacts and technological interventions). Thirdly, analogous to my account of conceptions of technological functions, the ICE-theory may also be understood as an account of aspects entailed in the conception of a technical function of an artefact relative to its use plan. In that way, the ICE-schema enables a sensible reconstruction of the conception the designer and/or users have in mind of the function of an artefact. For, the ICE-schema points out which aspects are relevant with regard to 'justifiable function ascription to artefacts, relative to their use plans'. Similarly, my second notion, 'the manifestation of a technological function' may account for 'the physicochemical capacity to $\phi$,' in the ICE-account. Also, the third notion, that is, 'the physical phenomenon which produces the technological function,' may account for the relevance of 'the causal explanation, or account, A, of the belief that the artefact has this capacity,' in the ICE-theory. In other words, this third notion may cover the causal explanation needed in an account of justifiable function ascription. Clearly, this latter comparison can only be very sketchy. Nevertheless, I suggest that the three notions proposed in this contribution may be suitable for developing an account of technological functions that accommodates both evaluative purposes *and* explanations of technological design and development.

**Authors' response: Wybo Houkes and Pieter E. Vermaas**

Analysing technical functions has been an interesting and challenging project not only because it implied charting a relatively unexplored domain but also because it involved revisiting a fairly large number of topics in subfields of philosophy. The comments by Erik Weber, Thomas Reydon and Mieke Boon again illustrate the versatility of the project: We are grateful for the comments from their perspectives of general philosophy of science, philosophy of biology and philosophy of engineering sciences, including the small excursion to the philosophy of religion. In our response, we follow the given order of comments.

To Erik Weber

Weber accurately summarizes the main findings and self-restrictions of our analysis in *Technical Functions* and then calls for exceeding one of these restrictions by proposing a fifth 'utility' desideratum for a theory of technical functions. We discuss his examples of cases in which functional explanations serve a 'heuristic' and 'substantial' role and offer some cases and reflections of our own concerning the need for and formulation of a 'utility' desideratum.

We agree that function ascriptions may serve a heuristic role in explaining the presence or persistence of artefacts and their properties. As argued explicitly by several authors (e.g. Strevens 2008), functional explanations 'black-box' several difference-making properties of a system and therefore at most indicate where a complete explanation is to be sought. Our ICE-theory clarifies some of the contents of the black box for functional explanations in the technical domain, such as a goal state, use plan, communication chain and original designer. We do not agree with Weber, however, that this non-finality of functional explanations makes them less useful than or 'inferior' to non-functional alternatives. In many practical contexts, it is useful to black-box the complete explanation, just as for users the capacity ascribed as a function to the artefact may be described in coarse-grained or goal-directed terms (e.g. as 'to remove dirt from laundry' rather than 'to lower the surface tension of water').

Because we insist on the utility of heuristic function ascriptions, we feel safe in disagreeing with Weber that diagnostic reasoning involves 'substantial' function ascriptions. Weber, following Lipton (1993), is right that the complete or final explanation of failed operations of an artefact differs from that of successful operations. Applying what Diamond (1997) has called the Anna Karenina principle, there are as many different complete explanations of failed operations as there are failures, whereas there is (ignoring, for the moment, design redundancies) only one explanation of success. Still, this does not entail that malfunctioning claims are irreducible elements of any specific complete explanation, nor that complete explanations of failure are independent of those of successful performance. Failure analysis would not be the complicated and painstaking branch of engineering that it is if a failure analyst could confine himself to making the claim that, say, Air France Flight 4590 crashed on 25 July 2000 because Concorde 'malfunctioned'. Rather, in combination with the complete explanation of successful performance, this claim should be a starting point for investigations into the candidate difference-makers between success and the catastrophic failure, such as the presence of debris on the runway or an overfilled wing tank.

This shows, in our opinion, that a 'utility' desideratum should be stated with considerable care, in order to prevent imposing unnecessarily high standards. To be more specific, we see no reason to regard function ascriptions as any less 'useful' because they play a 'merely' heuristic role, nor to think that they can only be 'substantial' if they feature irreducibly in complete or, in any context, superior explanations. More generally, and in answer to Weber's final and most important question, we think that an informative utility desideratum must look beyond the few aspects of artefact use and design that inspired the four desiderata of *Technical Functions*. Work on functions in the biological domain was, as Reydon rightfully remarks, in large part motivated by biologists' persistent use of functional explanations. Our own work was partly motivated by the persistent downplaying of technical functions by philosophers (of biology) and partly by the philosophical hypothesis that a complete characterization of technical artefacts should contain functional terms—a hypothesis that proved to be incorrect (see chapter 7 of *Technical Functions*). These somewhat introspective, philosophical motivations can and perhaps should be supplemented with attention for the role(s) of functional explanations in engineering disciplines. These roles are variegated and substantial, and engineers' intermingled use of functional, teleological and structural terminology is perhaps not immediately congenial to the ICE-theory or philosophical function theory (Vermaas 2010). Yet, this should not caution against stating an engineering-oriented utility desideratum, just against expecting fulfilment in the foreseeable future.

## To Thomas Reydon

Reydon focuses on another self-restriction of *Technical Functions*: the limitation of our ICE-theory to function ascriptions in the technical domain. Given that philosophical analyses of function were primarily motivated by biological discourse, this is a severe limitation—as also witnessed by our own attempts to exceed it, in considering how the ICE-theory might be applied to function ascriptions in the biological domain. We offer two application schemes and argue that the second, 'b-ICE' scheme seems most promising. Reydon offers three arguments against the feasibility of a b-ICE-theory of function ascriptions. We think, however, that the theory can be defended against all three arguments, which prompts us to reconsider briefly how seriously it should be taken.

Reydon's first argument is based on a contrast between the technical domain, where an artefact's original designers cannot incorrectly ascribe a function to it, and the biological domain, in which every function ascription by researchers might be mistaken. From this epistemic difference, Reydon concludes that an ICE-like theory, geared towards the first domain, cannot account for function ascriptions in the second domain. In response, we would want to point out that there are clear limitations to the authority that the ICE-theory lends to an artefact's designer. Function ascriptions by the designer do not, on the theory, 'cause items to have particular functions'. As a theory of function ascriptions, the ICE-theory offers no analysis of items *having* functions, let alone of what causes them to have these functions. Neither does the theory entail that function ascriptions by an artefact's original designers always amount to ascriptions of proper functions. On the ICE-theory, original designers are always right in ascribing *a* function to an artefact, at least if they offer adequate support for their ascription (designers of perpetual-motion machines are, for instance, never right). However, social privileging mechanisms determine whether original designers ascribe a *proper* function. Bell's ascription to the first telephone of the function to aid the hearing-impaired, for instance, never acquired the broad social acceptance needed.

Another supposed epistemic difference, motivating a second argument, concerns retrospective function ascriptions. Here, Reydon follows many philosophers in conflating designing with making or producing (Houkes and Vermaas 2009). On our reconstruction, designing involves constructing and communicating a use plan, which might involve only manipulations of naturally occurring items such as sticks and stones. Conversely, a technical function may be ascribed retrospectively to artefacts from an observer's perspective (95–96), for example, by archaeologists, by hypothesizing that the use of these artefacts consisted of executions of a communicated use plan. A b-ICE-theory allows a similar reconstruction of retrospective function ascriptions by biologists. What it does not do, however, is explicate the claim that 'biological items can have functions even if no researcher has yet studied them'. Yet this is by construction not a problem regarding function *ascriptions* and would therefore seem to fall beyond what can reasonably be expected of any theory of function ascriptions.

Finally, the kind allocation problem incorrectly assumes that function ascriptions determine artefact-kind membership. In fact, function ascriptions at most delineate what might be called 'instrumental classes' that loosely bind together items that serve similar practical purposes, for example, the wax-removal class that contains both special chemical detergents and brown paper (90). These classes are highly malleable and context sensitive: Your reading material may be, in a particular context, another's fish-and-chips-wrapping material. Moreover, the discussion of multifunctional substances and components in Section 6.1 of *Technical Functions* makes clear that not all artefacts unequivocally belong to only one instrumental kind. Considerations like this have led us and others, including Thomasson (2007, 57), who is brought up by Reydon, to conclude that function ascriptions do not in general determine kind membership for artefacts. Arguably, there are kind-determining intentions to be found, in manufacturing rather than designing and function ascription. This may substantiate the intuition that there is a difference between natural and artefact kinds, since the latter are ‘intention-dependent’. Yet it severs the connection between artefact kinds and the ICE-theory of function ascriptions. Consequently, there is no distinction between an ‘artefact-kind allocating’ and inflexible ICE-theory and a b-ICE-theory that fails to allocate (sufficiently flexible) membership of natural kinds.

This does not imply that we propose the b-ICE-theory as a serious rival to existing function theories for the biological domain. The main reason not to take it seriously, however, requires few arguments. It is stated immediately by Reydon, as well as in *Technical Functions*: The b-ICE-theory is a theory of *function ascriptions*. As such, it cannot compete with rival theories, which concern items *having functions*. Our responses show that the b-ICE-theory may be taken seriously as a theory of biologists ascribing functions to items, as long as one takes care not to read it as a theory of items having functions—a reading that, arguably, is needed to take the theory more seriously in the philosophy of biology.

To Mieke Boon

Boon’s comments concern the domain that *Technical Functions* is most immediately concerned with—that of engineered items. Boon claims that the relevance of our ICE-theory for this domain is hampered by the motivational role of theories of biological functions and by our focus on post hoc function attributions. In arguing for these claims, Boon constructs an ICE-theory of biological functions that fits a ‘deist-teleological’ view of biology; and she offers an alternative account of technological functions that, in supposed contrast to the ICE-theory, ‘accommodates the design and development of technological artefacts for performing desired functions’.

With regard to Boon’s claim about the motivation of our ICE-theory, we point out that the construction offered by Boon indeed captures well how a direct translation of the ICE-theory would reconstruct function ascriptions in biology. Such a translation is considered in *Technical Functions*, especially in the ‘as-if form’ that does not involve commitment to the existence of a Divine Creator (or Adam). Our reason for rejecting an ‘as-if translation’ is that the most central concept in the ICE-theory lacks a biological counterpart. For some biological items (e.g. organs), it may be possible to identify *users* (e.g. organisms) and even to claim that they *execute* use plans when they breathe or scratch their various itches. However, we guess that even outspoken theists would hesitate to claim that a Designer has communicated such use plans in detail to creatures, as in Boon’s rendition of the E-condition. Notably, use plans have disappeared in her gloss on this condition: Whereas she relates it to the reproduction of organisms (i.e. users), our condition concerns the reproduction of *use plans* through designer–user or user–user communication. Thus, Boon’s construction cannot capture the motivation behind the ICE-theory.

Boon’s claim about our focus on post-hoc function attributes is supported, not with arguments against the ICE-theory, but with an alternative proposal that features three related concepts: *physical phenomena* and the *conceptions* and *manifestations* of technological functions of artefacts. In what follows, we offer the outline of a comparative assessment of both function theories.

The ICE-theory gives a rational reconstruction of function ascriptions, by designers, users and observers. It unpacks such ascriptions in terms of justified beliefs about use plans for and the physicochemical capacities of technical artefacts, and about how these capacities contribute to the successful realizations of the use plans. This theory is only part of a full philosophical account of technology and the engineering sciences. Minimally, it needs to be supplemented with a theory of production and a theory of artefacts, as we also remarked in response to Reydon. Our use-plan approach can be extended to such a theory (Houkes and Vermaas 2009). Within these confines, we claim two comparative merits for our theory: a first, evaluative and a second, descriptive one.

Firstly, the use-plan analysis reconstructs the relation between designing and using as primarily one of transferring ways in which artefacts are to be used—their use plans—and secondarily transferring newly produced artefacts. On this basis, we categorize designing by distinguishing, for instance, between product designing as only designing new technical artefacts and designing proper as also developing a use plan for an artefact. By this distinction, the ICE-theory bridges a gap between the action-theoretical context of using artefacts and the physicochemical structure of artefacts. This gap is regularly ignored in accounts of the engineering sciences, by focusing exclusively on the ‘physical side’ of designing and leaving unanalysed how developments in these sciences lead to useful technologies.

Boon’s proposal illustrates this evaluative shortcoming. Creating a new type of paint with desirable features like resistance to scratching is a valuable engineering achievement, and Boon may be able to describe these achievements with her concepts. It is a familiar fact, however, that research and development in engineering do not always lead to useful technology. The ICE-theory, by bridging the gap between the use context of artefacts and their physicochemical structure may account for this fact. It tells that engineering development does not stop with creating artefacts with interesting capacities, but continues in designing i.e., in finding use plans that may be communicated to prospective users, thus arriving at a fully useful technology—and it may be used to *evaluate* design efforts in this respect. Boon, by contrast, leaves unanalysed how new materials may find their way into actual use contexts and therefore does not offer standards for design (or, in her words, development) comparable with ours.

Secondly, Boon is right that our ICE-theory is reconstructive and, as such, leaves it open whether the function ultimately ascribed to the artefact originally motivated its development. This, however, is an advantage over Boon’s own proposal, since the ICE-theory avoids the view that successful development requires realization of the original functional specifications. The history of technology, even after the rise of the engineering sciences, offers many examples of ‘accidental’ or ‘serendipitous’ development, where an item did not, or only very poorly, satisfy the functional specifications that it was developed for, but that was hugely successful with respect to other specifications. Illustrating this and the previous point, Spencer Silver accidentally discovered a reusable, pressure-sensitive adhesive in 1968, but it took six years and a clever idea from a colleague before these capacities of the material were employed in sticky notes, with tremendous commercial success (Petroski 1992, 84–86).

A more thorough assessment of both proposals should, of course, consider how Boon's account could be supplemented to repair the deficiencies sketched above; in particular, how such a supplement could differ from our use-plan analysis in such a way that Boon's proposal remains a genuine alternative to the ICE-theory. More importantly, however, we believe that, in line with the methodology of *Technical Functions*, it should set up clear desiderata that specify what should be done to 'accommodate' the design and development of artefacts and that specify to what extent and in which ways a theory of functions, rather than one of the artefacts, is accountable for this accommodation.

**Acknowledgments** The authors thank Raoul Gervais (Ghent University) for his comments on each contribution.

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