Chapter 10 On What is Made

Instruments, Products and Natural Kinds of Artefacts

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Abstract Debates in the metaphysics of artefacts typically start from the observation that technical artefacts result from intentional production and then focus immediately on the issue whether this 'mind-dependence' undermines claims that artefacts exist or come in natural or real kinds. We aim to add sophistication to debates on the latter issue by approaching it through an analysis of contemporary engineering and in continuity with discussions in the metaphysics of science. We first reconstruct which productive activities are involved in contemporary artefact production. From this reconstruction, we derive two general classification systems for artefacts – which we call the 'instrument' and 'product' systems. Then, we adopt from discussions in the metaphysics of science three conditions for classifications to correspond to natural kinds. For each of these three conditions, we discuss which conception or aspect of mind-independence it embodies, and to what extent our two classification systems meet it. We conclude that the instrument system is mind-dependent in all ways, and the product system only in some. Finally, we identify two options for finding natural classifications of artefacts, and develop the second as one that establishes continuity between the metaphysics of science and engineering. This second option leads to a classification system that can correspond to natural kinds, and that incorporates the product classes of technical artefacts extensionally.

10.1 Introduction

Our everyday world is filled with a large variety of human-made items.[1] Almost 150 years ago, hammers came in over 150 types in the Birmingham area alone.[2] In the 1990s, over 110,000 new types of packaged food and beverages were introduced in US supermarkets, which on average contain over 39,000 types of prod-

[1] Throughout the chapter, 'item' refers to objects and processes, which may or may not be human-made; 'class' or 'type' refers to a grouping of items, which may or may not constitute a kind.

[2] Basalla (1988).

ucts.[3] Moreover, the classification of these human-made items follows a large variety of guiding principles; hammers, for instance, can be classified in terms of primary purpose, intended use, shape and many other characteristics.

The general attitude in analytic metaphysics with regard to this multiplicity of classes and types of classes is one of indifference. Here, classes of human-made items, or of technical artefacts as we will call them, are typically taken as conventional ones that do not correspond to real or natural kinds. Starting point of recent debates on this topic is the observation that technical artefacts result from intentional production and that they are essentially characterised in terms that refer to human purposes and activities. This is taken to create a problem regarding their metaphysical status: since artefacts are the products of human activities and are therefore 'mind-dependent', they cannot come in metaphysically respectable kinds; or, even more strictly, they might just be aggregates of real entities (Van Inwagen 1990).

Amie Thomasson (2003; 2007a,b; 2009) has offered a forceful defence of the metaphysical admissibility of so-called *human kinds*, including artefact kinds. She argues that, although human kinds and their instances may depend on human interests and activities, this mind-dependence does not entail conventionalism. Indeed, she claims that this inference reveals a physicalist bias in metaphysics. In the natural sciences, classifications such as the periodic system of chemical elements may correspond to human-independent kinds. Yet in order to inquire, without begging the question, whether human-made items come in kinds, one needs a criterion without a physicalist or mind-independence bias. Thomasson proposes the following:

> for any essentially artifactual kind *K*, something is a *K* only if it is the product of a largely successful intention to make something of kind *K*, where such intentions must involve a substantive conception of what sorts of features are *K*-relevant and this conception largely matches that of some group of prior makers of *K*s (if there are any). (2009, p. 206)

As plausible or open-minded as this criterion may seem, it must be defended against two objections – or clarified in two respects.

The first is that intentions may indeed be relevant to the production of artefacts, but that it is, on closer analysis of engineering practice, unclear whose intentions in which productive activities are supposed to determine kind membership. Contemporary engineering differs considerably from the artisan model of production implicitly assumed by authors such as Thomasson, Lynne Rudder Baker (2004; 2007) and Risto Hilpinen (1992; 1993). They take production as the activity of an individual 'artisan' maker or designer, allowing the position that specific intentions of that individual maker or designer determine the kind the artefact he or she creates is a member of. Technical artefacts are nowadays typically the result of collective efforts, divided into a number of distinct designing and production

[3] Nestle (2002); FMI (2011).

phases.[4] A principled reason is needed to seek kind-determining intentions in one or more elements of this elaborate division of labour.[5] Another way to raise this point is to note that items described in the sciences and items described in engineering are treated asymmetrically in analytic-metaphysical discussions. With respect to the former, metaphysicians focus on the question which among the many classification systems correspond to natural kinds; with respect to the latter,they are more concerned with defending that artefacts exist at all, without too much attention for classificatory or engineering practices. Thomasson's criterion might succeed in giving this defence, but then raises the question which (if any) of the many classification systems, of say, hammers or packaged foodstuffs it favours: classifications in terms of primary purpose, in terms of intended use, et cetera. Or, conversely, which (if not every) of the classification systems it leaves vulnerable to criticisms regarding the respectability of artefact kinds.

A second objection is that, by proposing a criterion specific to artefact kinds, one might trade a question-begging case against such kinds for a question-begging case in favour of them. Advocates of the metaphysical respectability of any contentious classification system could, in principle, propose a criterion that saves realism regarding the classification. To avoid this second type of question-begging, a measure of continuity or resemblance should be established between the criterion for artefact kinds and conditions that have been offered for natural kinds in the sciences. This also allows investigating how the 'mind-dependence' of artefacts and their classification affects the applicability of each condition – in order to either make the best possible case for the metaphysical respectability of artefact kinds, or the most damaging case against them.

In this chapter, we present the results of a systematic search for natural kinds of artefacts. In an attempt to address the objections or worries voiced above, it proceeds via an explicit construction of classification systems and an assessment of these classifications in the light of conditions for natural kinds and the role of mind-dependence. We start, in Section 10.2, by reconstructing which productive activities are involved in contemporary artefact production. Developing our earlier action-theoretical analysis of using and designing in terms of use plans, we distinguish four productive activities: *designing*, *product designing*, *manufacturing designing* and *making*. This reconstruction adds *make plans* as a central concept to our earlier analysis. Then, in Section 10.3, we derive two general classification systems – which we call the 'instrument' and 'product' systems – each with their respective constitutive intentions. In Section 10.4, we introduce from the literature three conditions for a natural classification (Bird and Tobin 2008), where a natural classification groups together items in accordance with natural divisions rather than human interests, i.e., a classification the classes of which correspond to natural kinds. For each of the three conditions, we discuss which conception or aspect of mind-independence it embodies, and to what extent our two classification sys-

[4] Brown (2000) describes how divisions of labour in productive activities emerged in nineteenth-century engineering in the US and UK.

[5] This point is elaborated in more detail in Houkes and Vermaas (2009).

tems meet it. We conclude that the instrument system is mind-dependent in all, and the product system in some ways. Finally, in Section 10.5, we present our best case for naturalism with respect to artefact kinds.[6] We identify two options for finding natural classifications of artefacts, corresponding to part of the product classification system. The first option clarifies both Thomasson's view and the question-begging objection to it. The second puts more stock in establishing continuity between the metaphysics of science and that of engineering, and involves constructing a classification system that can correspond to natural kinds and that incorporates the product system extensionally. We conclude by identifying a remaining challenge.

10.2 A Rational Reconstruction of Engineering Production

In contemporary engineering, production of artefacts (including artificial processes) consists of multi-stage activities, in a division of labour between and within teams of agents. A presentation in an engineering-design textbook might represent production as starting with a client expressing a goal and, after steps such as goal reformulation, problem decomposition and testing, ending with artefacts to be used by agents. Typically, flowcharts illustrate the reconstructions, accompanied by disclaimers that real engineering-design processes are not as neat as suggested by the box-and-arrow diagrams.[7]

In our own analysis of artefact production, we take as a guiding principle that production is a goal-directed series of activities, where both the series and the different activities involved are subject to standards of (practical) rationality. This makes our result a *rational reconstruction* of production. It may be used as a basis for evaluating the various activities involved and does not fully reflect the complexities of actual practice.

Our reconstruction features four productive activities. In the order of their appearance in the analysis, these are *designing*, *product designing*, *manufacturing designing* and *making*. The activities of designing and product designing can be related to using through the notion of a use plan, as we showed in earlier work.[8] We briefly summarise this analysis immediately below. To extend our earlier results to manufacturing designing and making, we have introduced the notion of a *make plan*[9] and have argued that manufacturing designing relates to making as de-

[6] Following Bird and Tobin (2008), we distinguish kind naturalism (the view that some classifications are natural) from kind realism (the view that natural kinds exist independently of their members or instances).

[7] E.g., Hubka and Eder (1988); Roozenburg and Eekels (1995); Pahl et al. (2007).

[8] Houkes and Vermaas (2010).

[9] Houkes and Vermaas (2009). There, we called manufacturing designing simply 'manufacturing'; we changed our terminology in this chapter since, in engineering, manufacturing typically refers to both the planning of making and the making itself.

signing relates to using. Designing facilitates using: designing provides use plans by which users can realise their goals; manufacturing designing facilitates making: manufacturing designing provides make plans by which makers can create technical artefacts.

Of the four activities we distinguish, three – product designing, manufacturing designing, making – focus on the production of the item. A central difference with the artisan model of production as assumed in the work by Thomasson, Baker and Hilpinen, is that these three activities need not be conducted by a single agent. The assumption that the production of artefacts is in the hand of one artisan agent may already be an idealisation regarding pre-industrial times, where divisions of productive labour were not uncommon. In contemporary engineering, teams of agents are standardly involved in product designing, manufacturing designing and making.[10] Members of these teams may change during these activities, and their individual intentions may be incorrect, lost on others, or unrelated to the products they are absent-mindedly assembling (Kornblith 2007, sec. 2).

10.2.1 Use plans

Our inroad to the engineered world is to characterise its contents instrumentally, as items manipulated by agents to realise goals. To analyse the structure and context of these manipulations, we focus on ways of realising goals, and introduce *use plans* to spell out 'ways' as ordered series of considered actions; here, use plans can be distinguished from plans in general by their inclusion of interactions[11] with

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[10] The explicit distinction of separate activities in the production process and the coordination of the resulting division of labour in organisations may be a relatively recent phenomenon (Brown 2000). Engineering definitions of designing typically single out what we have called product designing, yet broader definitions that include use-plan designing can be found (e.g., Hubka and Eder 1988; Roozenburg and Eekels 1995; Brown and Blessing 2005). Manufacturing designing and making are in engineering clearly separated from (product) designing, although (product) designing may include the making of prototypes (Cross 2006, pp. 15-16). This separation is, for instance, described by Visser (2006, p. 160):"[t]he implementation (realization, manufacturing, fabrication, construction) of an artifact based on the specifications that result from the design, is [...] a different task from design, assigned to different professionals". And Chang (1990, p. 39) takes (product) designing as a process that ends with "a concept [for a physical entity that functionally satisfies a design requirement] expressed in a communicable media", and manufacturing as a means to realise that concept. Moreover, practices like concurrent engineering show that our conceptual distinction is reflected in an actual division of labour: it is generally acknowledged in engineering that this division of labour has led to new problems, requiring communication and adjustments of the activities by all agents involved.

[11] Interactions with items include physical manipulations (e.g., pressing, turning), remote causal interactions (e.g., accelerating space probes by means of Jupiter's gravitational field), and observations (e.g., watching traffic lights).

one or more items other than our own bodies. *Using* an item can then be defined as carrying out a use plan for that item. *Designing* is the activity aimed at developing new use plans. Sometimes, a newly designed use plan only involves interactions with existing and readily available items; then, designing is similar to advising or consultancy and mainly involves communicating the new use plan to whomever it may concern. We assume that in designing, the items involved in a use plan are described by the capacities that contribute to the successful execution of the use plan. This description may be enough to identify a suitable item, in case this already exists. In engineering design, the new use plans typically involve interactions with items that do not yet exist or are not readily available. Then, developing and communicating a new use plan is rational only if designing also contributes to making available the items needed. The non-existing or non-available items involved must be described in more detail than by their contributing capacities alone. Providing this description is the aim of a conceptually separate activity, which we call *product designing*. The specification of items to be produced, in words and images (e.g., blueprints), is typically regarded as the centrepiece of engineering design. Yet we take product designing as an activity that, if it is required at all, is subsidiary to the construction and communication of use plans.

To bring out some details of this reconstruction, let a use plan *up* for an item x be a series of goal-directed, considered actions in which interactions with x are included as contributions to realising the goal g_u of the plan. Let designing be the development of such use plans. Say, a market has developed for effortless nut cracking, giving rise to a goal g_u and a design task of coming up with a use plan *up* to realise the goal.[12] Ordinary nutcrackers require too much effort and may be unsafe, and industrial nut peelers are too noisy and expensive. So, a use plan is developed that makes reference to an item x with a specific capacity ϕ, defining a product-design task of describing x in more basic physical terms than the capacity ϕ. Let *id* refer to this 'item description.' We give general action-theoretical characterisations of designing and of product designing in the appendix to this chapter, Tables 10.3 and 10.4.

10.2.2 Make plans

An item does not come into existence by describing it. After product designing, the item should be made. In this part of engineering production, two activities may

[12] One might want to restrict use plans for an item x to those plans that feature prominent or salient interactions with x. This would prevent standard ways of cooking vegetables from being characterised as use plans for fresh water, and ways of cracking nuts as use plans for the nuts as well as the nutcracker. There is no hard and fast rule for determining in general which interactions are sufficiently 'salient': a variety of considerations, such as institutionalisation and regularity of use, comes into play when one answers, for an item x, the question "What do you use this for?" – or fails to provide a definitive answer, as in the case of fresh water.

be distinguished. The first activity, *manufacturing designing*, is aimed at developing a plan for making the described item, taking into account whether the item will be mass-produced, hand-made, tailor-made for individual users, or even made only once. The second activity, *making*, is aimed at actually producing the item. Manufacturing designing is distinguishable from product designing because even a full description of an item need not specify the actions required to make the item: the described items may be, literally, multiple realisable. Developing a goal-directed series of these actions, a *make plan*, characterises manufacturing designing. This conceptual distinction follows engineering practice, where manufacturing designing has become a profession in its own right. Manufacturing designing is designing: the series of productive actions, aimed at creating an item, involves the manipulation of materials and typically also tools. The make plan for an item x is then a use plan for a set of materials $\{y_1, y_2, ...\}$ and possibly a set of tools $\{z_1, z_2, ...\}$. Manufacturing designing may give rise to additional product designing, if the developed make plan involves non-existent materials, tools, machinery or even production plants. Making has in contemporary production become less a matter of specialised training and know-how. In our reconstruction, it amounts to carrying out plans developed in another activity, just like using.

Let *mp* refer to a make plan for an item x with description *id*. Let manufacturing designing be the development of such a make plan on the basis of the item description *id* of x as given by an agent a – typically the product designer. Manufacturing designing is aimed at contributing to the goals of other agents – the makers of x – to create x. So, on the basis of the item description of the household nutcracker, given by a product designer, the manufacturing designer develops a make plan for the nutcracker, which includes manipulations of materials and machinery. The make plan is communicated to makers, who carry out the plan and thus construct and assemble the nutcrackers. Step-wise characterisations of manufacturing designing and making are given in the appendix, Tables 10.5 and 10.6, again in general terms.

This part of our analysis of contemporary engineering practices brings out another difference with the model of production implicit in analytic metaphysics. Whereas Hilpinen (1992, §VI; 1993, §VI) and Thomasson (2007a, sec. 5) allow intentional selection as a limiting case of making, we explicitly require that making amounts to physically changing materials, either by physical modification of existing materials or by (non-trivial) assembly of those materials.

10.3 Two Classification Systems for Artefacts

There are many ways of grouping together human-made items, using, for instance, terms which refer to intended users (‘biker helmet’), primary purpose (‘swimsuit’), shape (‘U-bend’), material (‘wooden shoe’), mode of operation (‘nuclear plant’), or country of origin (‘French press’). Some of these colloquial groupings form more encompassing and systematic classifications than others. More contentiously, some classifications may group together items in accordance with natural divisions rather than (merely) human interests; others may be purely conventional. In the next sections, we will consider how to distinguish natural and conventional classifications of artefacts. In this section, we set the stage by organising and, to some extent, simplifying the subject matter. We show that, on the basis of the distinctions made in the previous section, two comparatively rigorous systems of classification may be constructed: the 'instrument' system and the 'product' system. Both classifications refer to intentional activities and systematise more colloquial ways to group items; yet they differ markedly in their scope and application.

10.3.1 The instrument system

As reconstructed in Section 10.2.1, the activity of designing consists in constructing and communicating a use plan *up* by which agents may realise a goal g_u. In executing this plan, these agents are meant to interact with various items because of the specific contributing capacities ϕ of these items.

This reconstruction of designing allows the construction of a classification system of items. First, the system makes a broad and general distinction between *instruments* and *useless items*. The class of instruments contains every item that is intended to be interacted with in at least one use plan; 'useless' are those items for which there is no use plan. Within the class of instruments, items may be grouped together in two different ways. A first subclassification refers only to the goals g_u to which interaction with the item is meant to contribute. Within these classes of 'goal instruments', a further subdivision can be made by referring to the use plan *up* that involves interaction with the item. An alternative subclassification refers to the goal-contributing capacities ϕ of the items classified as instruments. It can be shown that these contributing capacities ϕ are the technical functions.[13] Consequently, a subdivision of the class of instruments according to contributing capacities ϕ yields a function-based subclassification.

Table 10.1 The instrument system.

Instruments	items intended by designers to be interacted with in use plans
g_u goal instruments	items intended by designers to be interacted with in use plans with goal g_u
up plan instruments	items intended by designers as items to be interacted with in use plan *up*
ϕ functional instruments	items intended by designers as items to be interacted with in use plans for capacity ϕ

[13] Vermaas and Houkes (2006); Houkes and Vermaas (2010).

This leads to a general classification system (see Table 10.1) where 'goal-instruments' and 'plan-instruments' make up one subclassification, and 'functional instruments' another. We call the entire system the 'instrument system'.

This system applies to almost everything in the 'human-made world': ordinary household utensils; bicycles, trains and aeroplanes; heavy machinery, buildings and industrial installations; and the road system with its bridges and tunnels. The system also extends to the components of these items. The engines, pillars and screws that are parts of machinery, the road system and bicycles, respectively, are items that are interacted with in use plans – not always directly by the end users of these items, but minimally by the product designers who carry out use plans that involve these components when they incorporate the components in their product designs.[14]

Not only items that were created by humans can be called 'instruments'. We sit under trees for shade; wildlife is hunted or observed during safaris; and the stars are used for navigation. Thus, the instrument system applies across the natural-artificial border, where we find such items as wild or domesticated animals and plants, stars, and Dutch polders. Moreover, to call something an instrument does not entail that it sees regular or standardised use: the instrument system also applies to pebbles used as improvised paperweights, or flat stones that see single-time use in a game of stone skipping.

Subclasses of instruments may be distinguished according to goals – more specifically: according to the goal states of the use plan in which agents are supposed to interact with the items classified. The goal specifications and corresponding classes may vary in grain, from coarse – 'cleaning agents' – to fine – 'candle wax removers'. Even the more fine-grained goal classes of instruments typically contain a wide variety of items, as there are for instance many use plans with the goal of removing candle wax from fabric. One plan involves covering the spot of wax with a brown paper bag and ironing it; another plan involves covering the spot with ice cubes and chipping off the frozen wax; still another includes soaking the spot in carbon tetrachloride. All items interacted with in the execution of these plans may be grouped into the 'candle wax remover' goal class.[15]

As a counterpart to the 'multiple realisability' of most practical goals, most items are multiply usable: they may be interacted with in the course of executing different use plans, with different goal states. Pins, for instance, may be enrolled in the class of 'temporary materials connectors' but also in the class of 'position on map markers'; and brown paper bags and old fashioned flatirons are also in the goal classes of 'grocery container' and 'doorstopper', respectively.[16] The subsys-

[14] Vermaas (2006).

[15] In line with the considerations in n.12 above, one might want to restrict goal and plan classes to those items that are most 'saliently' interacted with for the purpose or when executing the plan. This would prevent candle wax from being classified as a candle wax remover, and the handlebar of a bicycle as a means of transportation.

[16] The example of flatirons used as doorstoppers may be discarded by some as due to recycled or 'improper' use; flatirons may in this vein be taken as only contained in the goal class of

tem of overlapping goal-instrument classes reflects many terms by which we refer to artefacts in everyday language: ‘container’ and ‘wax remover’ may, for instance, be taken to refer to different, but partly co-extensive goal classes. However, goal classes should not be taken to extend exclusively to artefacts. A specific natural sea sponge may, for instance, be called a ‘cleaning agent’ and ‘paint applier’ – since some painters manipulate them for cleaning their brushes, but also for applying paint to walls.

The use-plan analysis offers a means of subdividing goal classes into plan subclasses. Brown paper bags and irons are included in the ‘by-ironing’ subclass of the ‘wax-remover’ class, ice cubes in the ‘by-freezing’ subclass, etc. A classification on the level of use plans does not lead to unique class membership for the same reason as a classification on the level of goals does not: items typically are interacted with in more than one use plan, and therefore belong to multiple *up* plan classes. Even within a goal class, plan subclasses are typically not disjoint: water is interacted with in many plans for cleaning windows; paint features in many plans for decorating walls (as well as all plans for removing paint). One reason for this overlap is that stringent identity conditions may be applied to use plans, on which plans are different as soon as their goal states, included actions or the order of actions included are different.

Alternatively, instruments may be divided into subclasses according to the capacities by which they (are supposed to) contribute to realising goal states. The resulting functional subclasses group together items that have the same contributing capacities, irrespective of the goals for which and the use plans in which they are interacted with. The resulting subclasses are no more disjoint than the goal and plan subclasses. Some knives can be used for their capacity to spread paste-like materials like butter as well as for their capacity to cut materials like bread, which puts them in the functional class of ‘(butter) spreader’ as well as ‘(bread) cutter’.

There is no neat, general relation between the two ways of subclassifying instruments. On the one hand, functional subclasses are not necessarily more fine-grained than goal/plan subclasses. For instance, with respect to their most obvious intended capacity, knives may be grouped in the ‘cutter’ functional subclass – which is crude in comparison to classification of knives in terms of goals and use plans (e.g., preparing food, stabbing or performing surgery). On the other hand, goal and plan subclasses are also not more fine-grained than functional subclasses: both the brown paper bag and the iron are included in the ‘removing-by-ironing’ use-plan class, despite obvious differences in the capacities by which they are meant to contribute to the plan’s goal state.

The most fine-grained system of classifying instruments would refer to goal state, use plan and contributing capacities, all as intended by designers. Even this system would not capture all ways in which artefacts are grouped together in ordinary language. There, reference is made to characteristics that play no role in the

‘wrinkle removers’. The other examples are therefore chosen in a way that only proper use is considered.

use-plan reconstruction of designing, such as the size of items (‘microprocessor’), their colour (‘yellow submarine’), origin (‘French press’) and brand (‘a Ferrari’).

10.3.2 The product system

The instrument system focuses on designer’s intentions and functions – features that are often appealed to in philosophical analyses of artefacts. Instruments and their subclasses may therefore seem the only place to look for natural kinds of artefacts, or to argue that there are no such kinds to be found. Still, an alternative classification system may be constructed on the basis of our analysis of productive activities – in particular: on the basis of the intentions of manufacturing designers. We call this the *product system*.

As reconstructed in Section 10.2.2, manufacturing designers develop plans for making items that fit an ‘item description’ *id*. This description may be couched in physical, chemical and/or geometrical terms, and may refer to both categorical properties and dispositions. It may, moreover, be highly detailed or relatively sketchy. The class of products comprises everything made intentionally, where what matters are primarily the ‘creative’ intentions of the manufacturing designer, not those of the maker. More specifically, products are items that result from the execution of make plans (by makers) and that are thus intended (by manufacturing designers) to fit some *id*. Similar to Thomasson, we assume that executing a make plan includes a check whether the produced item fits the intended *id* (see the appendix, Tables 10.6). Products are therefore items that are accepted to fit an item description *id*.

The class of products can be subdivided by referring to the *id*’s, leading to subclasses of items that are intended to fit the same *id*. For components and food products, terms that indicate such ‘*id*’ subclasses are common: think of ‘PVC pipe’ and ‘chocolate mousse’. For many other products, *id*’s are available in the form of blueprints or drawings and descriptions in patents. Still, most *id*’s relevant to engineering practice would be too complex to be used in everyday language; proper names such as ‘Citroën DS’ and ‘Aspirin’ act as shorthand for such more complex *id*’s.

An even more fine-grained classification is obtained by adding a third, ‘made-product’ tier to the classification system, and specifying productive intentions more fully in terms of make plans *mp*. Since plans are partly identified by their goal state, and having items that fit descriptions *id* is the goal state of a make plan *mp*, the resulting classes of *mp* made products are subclasses of the classes of *id* made products. A simple example is the distinction between ‘hand-made’ and ‘machine-made’ items that may be superimposed on any *id* made-product class. The resulting ‘hand-made *id*’ and ‘machine-made *id*’ subclasses differ in the actions included in the make plans, but not in the goal state of the plans. Examples that are more relevant to engineering practice would be *mp* made-product classes that are differentiated on the basis of various industrial production processes, e.g., for casting metal objects. Furthermore, product (sub-)classifications that refer to materials, such as ‘wooden shoe’, can often be reconstructed as *mp* subclasses, since differences in materials used are typically reflected in differences in actions included in the make plan. Not all ordinary-language classifications of products may be reconstructed in this way: origin-based classifications (‘French press’), for instance, cannot be derived from differentiating features of make plans.

This leads to the product classification system depicted in Table 10.2:

Table 10.2 The product classification system

Products	items that are created by carrying out make plans
id made-products	items that are created by makers by carrying out make plans for items fitting description *id*
mp made-products	items that are created by makers by carrying out a make plan *mp* for items fitting description *id*

The class of products includes, like that of instruments, ordinary household utensils; bicycles, trains and aeroplanes; heavy machinery, buildings and industrial installations; and the road system with its bridges and tunnels. It also extends to many components, such as engines, pillars and screws, which are intentionally created in accordance with relatively autonomous make plans: they may be intended to be used as components of many different items; and execution of the make plans for components need not be spatially or temporally contiguous with the execution of the make plan of the items of which they are components. Moreover, similarity to a naturally occurring item is no reason to exclude something from the class of products. Water that is intentionally purified or intentionally made by burning hydrogen may be called a product; the same goes for artificial vitamins and, arguably, many domesticated animals and plants.[17]

The product and instrument classes do not coincide. Planets and pebbles, for instance, cannot be called ‘products’: our practical interactions with these items may not be reconstructed as execution of a make plan, but only of a use plan. Conversely, the class of products largely but not entirely lies within that of instruments, since most – but not all – make plans are constructed and executed in order to create items that are to be manipulated in carrying out use plans. Occasionally, however, manufacturing and making may be unrelated to use plans. Scientific or purely creative challenges may be candidates for such non-instrumental production activities. For instance, creating transuranic elements, artificial molecules such as Buckminsterfullerene, or synthetic organisms, just for showing that it can be done, may require the construction and carrying out of elaborate make plans. So, typically, do more quotidian challenges such as building the largest

[17] The make-plan analysis determines the focus of the arguments: a domesticated plant or animal may be called a ‘product’ if breeding it may be reconstructed as making – so, if there is a constructed and communicated make plan for the plant or animal. Genetic engineering of organisms can be reconstructed as such, and so can carrying out a deliberate breeding scheme; merely selecting plants or animals for desired properties can not.

sandcastle on the beach. The goal state of these make plans is to have items that fit highly specific item descriptions *id*, but that are not intended to be interacted with in any familiar use plan.

10.4 From Classifications to Mind-Independent Kinds

In the previous section, we presented two classification systems for artefacts, both based on reconstructions of contemporary engineering practices. We now turn to the question which of these systems, if any, may be taken as a natural classification.

We approach this question in the 'metaphysics of engineering' in continuity with the metaphysics of science. There, a central issue is to identify which, if any, scientific classification systems are natural, i.e., independent of human interests and conventions. Mendeleev's periodic system of the elements is a prime candidate for such a natural classification, whereas the classification of animals in the *Celestial Emporium of Benevolent Knowledge*, or the classification of baseball players by their fielding positions, is not. Since independence from human interests can, obviously, not be established directly, several more proximate conditions have been proposed for determining which classification systems might be regarded as natural. There appears to be no consensus about the list of relevant conditions, some of which are mostly used implicitly rather than stated explicitly. Moreover, the situation is complicated because several conditions have been brought forward in order to attack the very idea of natural classifications or natural kinds (e.g., by De Sousa 1984). Here, we focus on three conditions that are listed in an overview of work on natural kinds (Bird and Tobin 2008):[18]

1. *Intrinsicality*: Members of a natural kind share some or all of their intrinsic properties.
2. *Distinctness*. Natural kinds must be categorically distinct from each other.
3. *Stability*. Items cannot, after their creation, gain or lose membership of natural kinds without changes in intrinsic properties.

In this section, we apply these conditions to the instrument and product classification systems. Our primary purpose in doing so is to examine whether one of these systems may be regarded as 'natural' on the basis of these conditions. If either system is, a non-question-begging case is made for the metaphysical respectability

[18] Other conditions for natural classifications offered in the literature, but not considered here, include: that natural kinds support inductions or even laws of nature (Bird and Tobin 2008); that natural kinds form a kind (*ibid.*); that kind membership is unique (De Sousa 1984); that use of natural kinds is significant to the development of human knowledge (Hacking 1991); and that natural kinds are associated with real essences (Ellis 2001).

of artefact kinds. No specific criterion for the latter would be needed, since there would exist shared standards for the metaphysics of science and that of engineering. The standard might still be controversial, but this controversy would equally affect claims regarding natural classifications in science and in engineering.

The various conditions on natural classifications also appear useful with regard to specifying mind-dependence because they, in various ways, make explicit the idea that natural classifications are independent of “social and psychological facts about human beings” (Hacking 1991), or “objective” (De Sousa 1984). Failure to meet a condition therefore may correspond to a specific kind of mind-dependence.

Below, we review, for each of the three conditions, whether it is satisfied by (parts of) the instrument and product classification systems, and to what extent a failure to do so indicates the mind-dependence of artefacts and their classification.

10.4.1 The Intrinsicality condition

The Intrinsicality condition is based on the intuition that an item’s membership of some classification systems is determined by properties that the item has irrespective of its relation to, or even the existence of, any other items. The atomic number of chemical elements is a paradigmatic example of such an intrinsic property, whereas the human state of being jealous is not. Failure to meet Intrinsicality does not entail that items are mind-dependent: weight, for instance, is dependent on an external gravitation field and therefore not an intrinsic property, but it is not mind-dependent. Still, one might think that *because* artefacts depend on human intentions for their existence and their most characteristic properties, classifications of artefacts are bound to fail an Intrinsicality test.

To avoid jumping to conclusions, we examine in some detail whether the instrument and product classification systems group together items in terms of intrinsic properties. Both systems contain subclasses of which membership is determined by particular properties. Yet for most subclasses, these are properties of human activities, not of the items involved in them. For instance, an item belongs to a goal subclass in case someone intends it to be used for a particular purpose. Likewise, both use-plan and make-plan subclasses may group together items by characterising goal-directed, ordered series of intentional actions, which include interactions with the items. Returning to earlier examples, a *up* plan-instrument subclass may group together everything used to remove candle wax by ironing, and items in an *mp* made-product subclass may all have been made by hand. Thus, these classifications are strongly dependent on human activities in the sense that they group together items in terms of such activities.

Still, both classification systems include subclasses that, at least at first glance, characterise the properties of items, and not those of activities – namely, functional instruments that share a capacity ϕ, and *id* made-products that share an item description *id*. On closer inspection, the former fails to specify an intrinsic property. Not only may the item fail to have or manifest ϕ, but even if it has or manifests ϕ, this depends on human beings interacting with it (or just intending to interact with it) in specific ways. An item is not a member of the functional instrument subclass of, say, water tanks in virtue of, among other things, its impermeability, but because it is intended to be manipulated in specific ways for the purpose of containing water. Not all water tanks are in fact impermeable, and even for those that are, or would be if used, their impermeability does not in itself determine class membership, although it may explain why their possible use for the purpose would be successful – the kerosene tank of Air Force Number One is impermeable, but not a member of the functional instrument subclass of water tanks, since it is not to be expected that someone has developed the associated use plan for the tank.

By contrast, *id* made-products appear to share intrinsic properties. By definition, membership of these classes is determined by the item description *id*, which consists of categorical or dispositional, physical, chemical or geometrical properties – such as size, material composition, conductivity and/or permeability. In principle, items that are intentionally produced can be identified independently of any considered use. Thus, 'marble sphere with ten-centimetre radius' identifies a class of *id* made-products irrespective of any interaction with, including purposeful manipulation by, human beings.

Despite first appearances, however, membership of *id* made-product classes is not mind-independent. For one thing, all items in these classes are created intentionally. A ten-centimetre radius marble sphere formed by some freak geological event would not qualify as a member of the *mp* made-product class. Moreover, not nature but the decisions of product and/or manufacturing designers determine which properties feature in an *id*. The items in the subclass may share other properties: all considered marble spheres with a radius of ten centimetres may, for instance, be made with marble from the same quarry – but only accidentally so unless this is specified in the defining *id*, the contents of which are determined in the human activities of product designing and manufacturing designing.

Summing up, both the instrument and the product classification systems are revealed as mind-dependent with respect to the Intrinsicality condition, albeit in different ways.

10.4.2 The Distinctness condition

The Distinctness condition features on several lists offered in the literature, e.g., in De Sousa's (1984) condition of "sharp boundaries" and Hacking's (1991) "definability". It is motivated by the intuition that membership of natural kinds cannot be indeterminate, since that would require human beings to arbitrate to which of two gradually merging kinds an item belongs. Thus, failure to meet Distinctness entails a specific kind of mind-dependence of classes – conventional or subjective boundaries – which would undermine the naturalness of a classification system.

Consider, in this light, goal classes and functional classes in the instrument system. The 'removing wax' and 'removing grease' goal classes, or the 'storing milk' and ‘heating milk’ goal classes may be readily distinguished: few items are, intuitively, in grey areas between these classes, so that arbitration seems uncalled for. However, other goal classes do merge gradually into each other. Some items, for instance, are as much playthings as educational materials (or are at least advertised as contributing to both entertainment and education), whereas other items are quite clearly only for play or for education. The reason is, of course, that some human activities serve multiple purposes, or achieve one thing by striving for another. In many such cases, neither goal is subsidiary to the other and neither requires realisation of the other. If a non-arbitrary line between the resulting, gradually merging goal classes can be drawn at all, it would require a close examination of individual human motivations.

For functional classes, the indistinctness of the capacities ϕ presents additional problems. As alluded to above, these capacities may be described in both coarse-grained and very fine-grained terms. Most of us would, for instance, describe the capacity for which a tablet of Aspirin is most regularly used as ‘alleviating pain’. Pharmacologists might (or should), however, replace such a coarse-grained, goal-directed description with one that specifies how the tablet and its ingredients are intended to affect physiological mechanisms. One might even specify different classes of painkillers, in terms of more fine-grained, physiologically distinct capacities. Such distinctions, or the need for such distinctions, depend not only on the availability of relevant knowledge (which affects every classification), but also on the social need for such knowledge. Drawing the line between various kinds of painkillers is unnecessary for most users, and its necessity for experts arises from the intended usage (e.g., facilitating regular use without side-effects, or predicting overdose effects) rather than intrinsic properties of the items. Alcoholic beverages may, for instance, be distinguished according to precise physiological effects just as painkillers – but their usage does not typically require such distinctions.

Turning to the product system, *id* made-product classes appear to be sufficiently distinct. The item descriptions *id* may contain vague terms, such as ‘brittle’, ‘long’ or ‘sharp’. However, as the reconstruction of manufacturing designing makes clear, this activity requires an agent to specify vague terms in the description *id* at least up to the point that the results of making can be evaluated. Hence, *id*’s should be definite enough to facilitate checks in manufacturing designing: classes of ‘*id* made products’ therefore single out kinds that are just as distinct. On closer inspection, the stringency with which these distinctions are imposed reveals a further dependence on human interests. Items used in official sports tournaments are, for instance, subject to highly specific *id*’s, whereas far less specific *id*’s apply for similar items used in playgrounds. Furthermore, the *id*’s of many made products contain continuously variable properties, such as length or amount of an active ingredient. Whether and how these are made discrete in *id*’s is strongly interest-dependent. PVC pipes, for instance, come in many lengths, which would seem relevant in the *id*’s that guide their production. This would mean that PVC pipes either come in as many distinct kinds as they are applied for, or in one kind that is indistinct in one aspect of their~~its~~ *id*. Tablets of Aspirin, to give another example, come in several distinct dosages of acetylsalicylic acid. However, the distinctness of this aspect of their *id* depends on distinct applications by human beings (e.g., for children, for adults, for daily use, for incidental use), not any distinction 'in nature'. Furthermore, professionals and experts may specify properties in the *id* such as 'toughness' or 'flexibility' in less coarse-grained terms, because there is practical interest in doing so.

Summing up, both the instrument and the product system are lacking in terms of Distinctness. These lacks reflect various dependencies of artefact classification on human interests. Some items are classified in indistinct instrumental classes because we value their usefulness for multiple purposes; and the distinctness of any artefact classification depends on our interest in specifying it. For instruments, such a specification would involve determining the relevant intentions or actions, revealing a rather fundamental mind-dependence. For *mp* made-product classes, there is also a fundamental mind-dependence in the (specification of the) productive actions that determine class membership.

10.4.3 The Stability condition

The Stability condition for natural classifications is controversial. It is explicitly required by some (e.g., De Sousa, who goes on to show that no classification system is in fact stable); implicitly appealed to by others (e.g., Bird and Tobin); and mentioned as an optional feature by still others (e.g., Ellis, who distinguishes between fixed and variable natural kinds). Like Intrinsicality, failure to meet Stability does not entail that a classification system depends on human interests, but just that items may lose membership of some classes or gain that of others. However, for artefacts, one may suspect that this dynamics is not intrinsic, but reflects changes in human interests.

The class of instruments and its subclasses confirms this suspicion, since they depend on the demands of users and on the state of the art in engineering design. In modern engineering practice, this state of the art can change quickly. In particular, the constant construction and adoption of new use plans leads to an intricate dynamics of instrumental subclasses. Membership of the different instrumental subclasses is highly context-dependent, where common knowledge and acceptance of use plans provide much of the relevant context. Items that are members of one subclass (goal, plan or functional) may become members of other subclasses, even without physical modification. Tablets of Aspirin have, for instance, long been members of the goal and functional class 'painkiller', but have recently also become members of the goal and functional class 'blood-thinner' and may be on the verge of being enrolled in that of 'anti-carcinogenic'. Conversely, technological developments may make use plans obsolete, causing items to lose membership of instrumental subclasses or, in rare cases, of the class of instruments altogether. A case of subclass drop-out is plate armour, which went from the goal and functional class 'protective gear' in mediaeval times to 'ceremonial garb' in the seventeenth and eighteenth centuries and 'decoration' or 'museum exhibit' in the present age.

The product system is more stable. In particular, *id* made-product classes single out items by the item description *id* that is the goal of the make plan that led to the item. Therefore, an item retains membership of an *id* made-product class throughout its lifetime. Embedding it in a different context of use, i.e., including interactions with the item in a use plan that did not prompt the construction of its make plan, is irrelevant to this: it changes or adds to the item's functionality, without changing the item's membership of its original *id* made-product class. Tablets of Aspirin are, for instance, created as members of 'tablets-containing-*x*-milligrams-of-acetylsalicylic-acid' subclasses. This remains the case after Aspirin is recognised to reduce blood clotting or to prevent tumour growth and is included in new goal-instrumental subclasses. Tablets of Aspirin would even remain in their original *id* made-product classes if any or all of their uses would become obsolete and they would consequently no longer be called 'painkillers' or even useful.

Furthermore, since executing a make plan, on our reconstruction, requires at least one physical modification of the item or of its constitutive materials, Cambridge changes are ruled out: something cannot lose membership of an *id* made product class without a modification of at least one of its intrinsic properties. However, not every modification counts. Ordinary wear and tear will affect some of the properties of an artefact, and some of these changes may be compatible with the artefact remaining to meet its original *id*, meaning that it does not lose its *id* made-product class membership: friction changes the profile of tires and the sharpness of knives, but these changes may be within set limits. Yet eventually the changes may be such that an artefact would not meet its original *id*, and that may even be after a short period of use. The item then loses membership of its original *id* made product class. In this case, it may be still re-made, meaning that there has been a new cycle of manufacturing designing and making, and possibly also of plan and product designing – for instance, in maintenance, refurbishment and recycling. Here, somewhat paradoxically, the stability of class membership despite changes in properties reveals another aspect of the mind-dependence of the product classification system – namely human expectations regarding changes in or even loss of the properties that determine class membership.

10.5 Two Ways to Find Natural Kinds of Artefacts

The discussion in the previous section shows that neither the instrument nor the product classification system of artefacts has a strong claim to being natural. The instrument classification system does not meet any of the three conditions considered. The product classification meets Stability at the level of *id* made-product classes, and it comes close to meeting Distinctness and Intrinsicality at the same level – but being close does not count in analytic metaphysics. As discussed, these failures reflect in various ways how artefacts and their classifications depend on human interests and activities.

Still, we argue in this section that there are at least two options for maintaining the view that, despite their mind-dependence, artefacts come in natural kinds.

A first option is to acknowledge that the mind-dependence of artefacts makes it impossible for their classifications to meet all three conditions, but that some classifications of artefacts may still be taken as natural. More specifically, one might argue that one or more of the conditions considered in the previous section should be relaxed to accommodate one or more systems of artefact classification. Thomasson's view, presented in Section 10.1, embodies this option: it involves weakening the Intrinsicality condition by allowing that intrinsic properties may be related to productive intentions. Thomasson defends this by accusing the original Intrinsicality condition of a physicalist bias and therefore of begging the question against the metaphysical acceptability of artefact kinds. Rephrased in terms of our own results, Thomasson proposes to take as a natural classification the grouping of artefacts into *id* made-product classes. This classification meets the modified Intrinsicality condition, and our make-plan analysis adds a more precise identification of the constituting intentions of kinds as the intentions that come with make plans.

This option and its implementation need not or should not convince orthodox analytic metaphysicians, for two reasons. First, the original Intrinsicality condition spells out the basic intuition behind distinguishing natural and conventional classifications, an intuition that is lost by weakening this condition. This makes the new Intrinsicality condition vulnerable to the charge that it, and not the original condition, begs the question and that it does so in favour of natural classifications of artefacts – specifying the charge against Thomasson's view presented in Section 10.1. Second, whatever changes are made to the Intrinsicality condition, the *id* made-product classification still only approximately satisfies the Distinctness condition. Hence, those taking the first option should weaken, adjust or challenge two conditions, both of which make explicit in different ways the idea that natural classifications should be mind-independent.

We therefore present a second option for finding natural classifications of artefacts, which does not involve weakening the Intrinsicality condition.

Let us return to the analysis given in the previous section about how *id* made-product classes violate the Intrinsicality condition. As noted there, membership of an *id* made-product class is not determined by intrinsic properties, but by the make-plan-constitutive intentions to produce items with intrinsic properties – let us call these properties *p* – that are included in the item description *id*. We can now observe that, at least for moderately complex technical artefacts, the *id* made-product class has the same extension as the class of items that have the properties *p* specified by the *id* of the class. For, as Reverend William Paley famously pointed out in another context, there simply are no 'swamp watches' (or 'heath watches'), i.e., there are no naturally occurring items that have the properties *p* that are included in the *id* of any class of watches.

This observation allows the introduction of a classification system of artificial items that share specific intrinsic properties *p*. For each class of *id* made products, there is a corresponding class to which items belong because they have intrinsic properties *p* contained in the item description *id*. By construction, this '*p* classification system' meets the Intrinsicality condition: the intrinsic properties *p* determine class membership. Moreover, the *p* system meets the Stability condition in largely the same way as the *id* made product classification system: items are members of a *p* kind if and only if they have intrinsic properties *p*, and changes in the intrinsic properties of items cause items to lose or gain membership of specific *p* kinds.

These considerations do not establish that the product classification system of technical artefacts is natural. Rather, we have shown that, for *id* made-product classes of moderately complex technical artefacts, there are classes with the same extension that satisfy Intrinsicality and Stability. This allows no more (or less) than the conclusion that the classes of aeroplanes, watches and other non-naturally-occurring items are 'natural-by-proxy'. *Id* made-product classes of other, less-complex artefacts are extensionally *included* in *p* classes. Members of such classes can come into existence by either natural processes or intentional production. Examples are water, Aspirin and marble spheres (assuming that freak geological phenomena can create such spheres).

The natural sciences may already group together naturally occurring members of such classes in terms of their intrinsic properties *p*. What engineering, reconstructed as in Section 10.2, adds are *non-naturally-occurring* items with intrinsic properties *p*, where these properties can be the same as the intrinsic properties *p* acknowledged by the sciences for naturally occurring items. Now, if one takes the scientific groupings to correspond to natural kinds, it seems parochial to exclude the non-naturally occurring items as members of these natural kinds: if one takes – as per the Intrinsicality condition – the intrinsic properties *p* as determining kind membership, excluding some items that have *p* just on the basis that they were created to have *p* is a question-begging exception to one's own criterion of admittance. Taking this argument one step further, it is equally parochial to exclude *non-naturally-occurring* items with intrinsic properties *p* that are different from the intrinsic properties *p* acknowledged by the sciences for naturally occurring items. Non-naturally-occurring items define *p* classes that meet Intrinsicality just as much as *p* classes of naturally occurring items; excluding the former *p* classes to correspond to natural kinds just on the basis of that they contain mainly or only members that were created to have *p* is again a question-begging exception to the criterion of admittance.

This second option for arguing that artefacts come in real kinds also goes some way towards meeting Distinctness. Physical and chemical *p* kinds are, arguably, sufficiently Distinct, whether their members are naturally occurring or not. By contrast, human interests may determine how the boundaries of artificial *p* kinds with more complex properties are identified. It is not immediately clear, however, that a specific problem regarding artefact kinds remains here. First, debates regarding metaphysical indeterminacy (e.g., Van Inwagen 1990) or epistemic and semantic vagueness (e.g., Williamson 1994) may simply take problems regarding the boundaries of artificial *p* kinds in stride. Moreover, one might draw a parallel between artificial *p* kinds and biological species. Arguably, these are natural kinds, but their boundaries are not sharp, and drawing boundaries may involve discretisation of continuously varying properties – like what was discussed as a problem for some artefact classes in Section 10.4.2 above. Again, the interest-dependence of the discretisation of (a limited number of) artificial *p* kinds may not present a specific problem. Thus, problems with regard to Distinctness may not arise for all artificial *p* kinds and, even when they do, may not be specific to such kinds.[19]

Supposing that Distinctness can be met along one or more of these lines, the second option discussed here leads to the following combined picture of kinds in the natural sciences and engineering.[20]

On the one hand, one may distinguish natural kinds in terms of the theories or disciplines that deal with their intrinsic properties *p*: physical kinds (e.g., elementary particles), chemical kinds (e.g., chemical elements and complex molecules) biological kinds (e.g., species) and artificial kinds (e.g., specific aeroplanes and watches). On the other hand, irrespective of controversies regarding the distinctions between these natural kinds or regarding specific examples of natural kinds, one may distinguish natural kinds in terms of the processes that bring its members into existence: by naturally occurring processes alone, by intentional production alone, or by either. The third type extensionally includes *id* made-product classes, the second type coincides with them; only the first has no overlap with any *id* made-product class. Technological advances make it increasingly difficult to find examples of 'purely naturally occurring' kinds – although creating members of the barred-spiral-galaxy kind lies far beyond presently conceivable human capabilities. Changes in these capabilities also continue to reveal new natural kinds, such as transuranic elements and Buckminsterfullerene molecules; and, less dramatically, it makes it possible to intentionally create members of existing natural kinds, such as diamond and acetylsalicylic acid.

On this second option technical artefacts have a relatively straightforward status within analytic metaphysics, while staying close to orthodox intuitions about natural kinds: *id* made-product classes for which intentional production is necessary to realise members of the classes, are extensionally equal to related *p* natural kinds; and *id* made-product classes for which members can also come into existence by other processes than intentional production, are extensionally within related *p* natural kinds. All technical artefacts that are the result of carrying out a make plan are therefore members of *p* natural kinds, and are thus to be taken as respectable within analytic metaphysics. Moreover, if weak realism for natural kinds is

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[19] We would like to thank Maarten Franssen and Thomas Reydon for suggesting some of these ways of meeting the Distinctness condition.

[20] Our focus on natural kinds identified in physics, chemistry and biology should not be taken as expression of a view that other disciplines, such as the behavioural, cognitive and social sciences, do not identify natural kinds.

accepted as defined by Bird and Tobin (2008), then all these technical artefacts are also members of real kinds.

Acknowledgments Our thanks to Maarten Franssen, Peter Kroes and Thomas Reydon for their comments on an earlier draft of this chapter. Research by Wybo Houkes and research by Pieter Vermaas was supported by the Netherlands Organisation for Scientific Research (NWO).

Appendix: Action-Theoretical Descriptions

Table 10.3 Designing

D.1	The designer d wants to contribute to a user's goal of bringing about a state g_u.
D.2	d believes that the state g_u' is the closest consistent and viable approximation of g_u, and intends to contribute to bringing about g_u'.
D.3	*d* believes that if the users follow an appropriate use plan *up* that involves the interaction with items $\{x_1, x_2, \ldots\}$, this will contribute to bringing about g_u', and intends to construct this plan *up*.
D.4	*d* intends to contribute to producing the items x_i, x_j, etc., that do not yet exist by *product-designing* them.
D.5	*d* intends to communicate *up* to the users.
D.6	*d* believes that g_u' can or cannot be brought about by the users to whom *up* is communicated. This belief is based on the observation that some users go through a sequence of actions *up'* and bring about g_u'', and on a comparison of g_u'' with g_u'.
D.7	*d* decides that her goal to contribute to bringing about g_u' has been achieved or not. In the latter case, *d* may decide to repeat the entire *D* sequence, settle on another plan (return to *D.3*), re-product-design at least one of the items x_i, x_j, etc., (return to *D.4*) or re-attempt communication (return to *D.5*).

Table 10.4 Product designing

PD.1	The designer *d* believes that an item *x* with physicochemical capacity ϕ does not exist.
PD.2	*d* intends to contribute to realising the goal state g_{dx}, consisting of the existence of a description *id* of an item *x* with physicochemical capacity ϕ.
PD.3	*d* intends to describe an item *x* with physicochemical capacity ϕ for realising g_{dx}.
PD.4	*d* believes that a composite of the components $\{c_1, c_2, \ldots\}$, where c_1 has capacity ϕ_1, c_2 has capacity ϕ_2, etc., has the desired capacity ϕ.[21]
PD.5	For each component c_i, *d* intends to contribute to bringing about the goal state g_{dci}, consisting of the existence of a description of an item c_i with capacity ϕ_i; if *d* believes that this item c_i already exists, then design task g_{dci} is fulfilled by describing this item. If *d* believes that this item c_i does not exist, then another decomposition step *PD.4*, component design task step *PD.5* and integration step *PD.6* is made in order to fulfil design task g_{dci}.
PD.6	*d* believes that the various design tasks g_{dci} are fulfilled simultaneously, i.e., that the item *x* composed of the described components $\{c_1, c_2, \ldots\}$, has the capacity ϕ.
PD.7	*d* intends to communicate the description *id* of item *x*, possibly along with instructions for production and assembly of it and/or its components to appropriate agents.

[21] In principle one can have only one component, in which case *x* is equal to c_1 and ϕ is equal to ϕ_1.

Table 10.5 Manufacturing designing

MD.1	The manufacturing designer *md* wants to contribute to a maker's goal of bringing about an item *x* as described with description *id* by the agent *a*.
MD.2	*md* believes that an item *x′* is the closest consistent and viable approximation of *x*, and intends to contribute to bringing about *x′*.
MD.3	*md* believes that if the makers follow an appropriate make plan *mp* that involves the manipulation of materials $\{y_1, y_2, \ldots\}$ and tools $\{z_1, z_2, \ldots\}$, this will contribute to bringing about *x′*, and intends to construct this plan *mp*.
MD.4	*md* intends to contribute to producing the items y_i, y_j, etc., that do not yet exist by *product-designing* them.[22]
MD.5	*md* intends to communicate *mp* to the makers.
MD.6	*md* believes that *x′* can or cannot be brought about by the makers to whom *mp* is communicated. This belief is based on the observation that some makers go through a sequence of actions *mp′* and bring about *x″*, and on a comparison of *x″* with *x′*.
MD.7	*md* decides that her goal to contribute to bringing about *x′* has been achieved or not. In the latter case, *md* may decide to repeat the entire *MD* sequence, settle on another plan (return to *MD.3*), re-product-design at least one of the items y_i, y_j, z_k, z_l, etc., (return to *MD.4*) or re-attempt communication (return to *MD.5*).

Table 10.6 Making

M.1	The maker *m* wants to bring about the existence of an item *x* as described by description *id* by an agent *a*.
M.2	*m* either chooses from a set of available alternatives a make plan *mp* for bringing about the existence of *x* that involves the manipulation of materials $\{y_1, y_2, \ldots\}$ and tools $\{z_1, z_2, \ldots\}$.
M.3	*m* believes that the physical circumstances support realising *mp* and that he possesses the necessary skills.
M.4	*m* intends to carry out *mp* and acts accordingly.
M.5	*m* observes *x′* as the outcome of *mp* and compares *x′* with *x*.
M.6	*m* believes that *x* has been brought about or not. In the latter case, he may decide to repeat the realisation of *mp* or to repeat the entire *M*-sequence.

[22] If, say, the right machines for making *x* singled out by the manufacturing designer *md* do not yet exist, she may decide to let them be made first. This turns making into an iterative process: items are made with items that were previously made.

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