Research Article

Toward a Realizable-Centered Approach to Artifacts in Applied Ontology

Applied Ontology
1–40

DOI: 10.1177/15705838261447740
journals.sagepub.com/home/apo

Fumiaki Toyoshima[1], Adrien Barton[2] and Kathrin Koslicki[1]

Abstract

We provide a theoretical foundation for a formal ontology of artifacts based on the notion of a realizable entity: a property that can be realized in associated processes of a specific correlated type in which the bearer participates. This realizable-centered approach to artifacts aims to accommodate a wide range of artifacts, from technical artifacts (e.g., screwdrivers) to artworks (including ready-made artworks) and spiritual artifacts (e.g., amulets), making it applicable across diverse fields such as engineering, art, anthropology and archeology. It is motivated by limitations of function-based accounts of artifacts and the needs for a meticulous analysis of their intentional dimension. To articulate various usages of the term "artifact," we introduce two key notions: *canonical artifact* (an entity intentionally produced for a specific purpose) and *usefact* (an entity intended to be used for some accidental purpose). We provide a realizable-based characterization of both, classifying intentions as a subtype of realizable entities. We argue that our realizable-centered approach is more general than three prominent function-based theories of artifacts: designer-based, etiological and systemic. We further demonstrate that our framework can be adapted to Basic Formal Ontology (BFO), highlighting its flexibility and broad applicability.

Keywords

artifact, realizable entity, intention, function, Basic Formal Ontology (BFO)

Received: August 13, 2024; accepted: April 20, 2026

1 Introduction

1.1 Background and Motivation

The world is brimming with artifacts. To name just a few, there are technical artifacts (e.g., screwdrivers), artworks (e.g., paintings), social artifacts (e.g., the European Commission) and abstract artifacts (e.g., software and Shakespeare's work *Hamlet*). These types of entities are usually contrasted with so-called "natural objects" such as molecules, stones, people and planets. They are intimately connected with many kinds of entities such as intentions, agents, actions (physical and mental), capabilities, capacities, functions, roles, and affordances. Artifacts are notoriously difficult to analyze ontologically because no clear consensus exists yet over how to understand systematically a number of different ontological characteristics of artifacts.

In this paper we will develop a new approach to the formal ontology of artifacts. Let us begin by explaining the general motivation behind our work. First, artifacts have been traditionally investigated in terms of functions, as is illustrated by the example of screwdrivers and the function to turn screws. There may be nonetheless some problems with the function-based accounts of artifacts. One theoretical problem is about their generality. While technical artifacts may be generally explicable in terms of functions to some degree, it is controversial whether so are all the kinds of artifacts as well (Franda

[1]Institut de philosophie, Université de Neuchâtel, Neuchâtel, Switzerland
[2]Institut de Recherche en Informatique de Toulouse (IRIT), CNRS, Université de Toulouse, Toulouse Cedex, France

Corresponding Author:
Fumiaki Toyoshima, Institut de philosophie, Université de Neuchâtel, Espace Tilo-Frey 1, 2000 Neuchâtel, Switzerland.
Emails: fumiaki.toyoshima@unine.ch; toyo.fumming@gmail.com

& Souman, 2025; Houkes & Vermaas, 2009b; Juvshik, 2021b; Koslicki & Massin, 2025, in press; Olivero, 2019; Raven, 2025). For instance, what would be, if any, the function of Leonardo da Vinci's *Mona Lisa*? This question may be difficult to answer straightforwardly, given the variety of theories of functions as well as desiderata for a satisfactory theory of functions in the literature (Artiga, 2011, 2016; Röhl & Jansen, 2014; Wouters, 2005).

One related, practical problem with the function-based accounts of artifacts is that they could yield conceptual and linguistic confusion in the development of domain ontologies. This is because the term "function" has been used differently in different domains and upper ontologies, or even within specific domains such as engineering (Carrara et al., 2011; Yargan & Jansen, 2024). To take one simple example, the definition of the term "material artifact" as "a material entity that has some function" may be differently interpreted and formalized, according to different views of functions. This may, in turn, exacerbate the problem of the lack of semantic interoperability between information systems (Gardner, 2005), as it is arguably the case that: "neither in philosophy nor in formal ontology is there a generally accepted theory of functions. In particular, there is no consensus how to include functions into a top-level ontology or whether to include them at all" (Röhl & Jansen, 2014, p. 1).

Second, it is widely acknowledged that artifacts have an intentional dimension. However, there may be room for further exploration of the intentional dimension of artifacts. Suppose that I shaped and dried an amount of clay with the intention that it will be capable of containing liquid. What is, ontologically speaking, my intention to shape and dry this amount of clay in such a way as to be able to contain liquid? What kind of ontological relation holds between my intention and my intentional act of shaping and drying the clay to be able to contain liquid? What are the relationships among my intention, my intentional act and the resulting clay pot? These questions must be addressed by a complete analysis of the intentional dimension of artifacts. For instance, Borgo and Vieu (2009, p. 291) say: "although we need to model intentional aspects [of artifacts], we will avoid as much as possible the direct reference to theories of mental attitudes, which are not *per se* the subject of this paper and are by no means consensual." Although there may be no solid consensus as to an ontology of mental attitudes such as intentions, it will constitute an important step toward a comprehensive ontology of artifacts to analyze the intentional dimension of artifacts in terms of some specific ontological account of mental reality.

To summarize, we are motivated to develop an alternative theory of artifacts in the field of formal ontology, partly because of the theoretical and practical limitations of function-based accounts of artifacts, partly because of the needs for further study of the intentional dimension of artifacts.

1.2 Purpose

The objective of this paper is to provide a theoretical foundation for a formal ontology of artifacts on the basis of the ontology of *realizable entities*, extending our previous works (Toyoshima et al., 2024a, 2024b).[1] A realizable entity is a property that can be realized in associated processes of a specific correlated type in which the bearer participates. For example, the fragility of a particular glass can be analyzed as a realizable entity whose bearer is this glass and which can be realized in a process of the glass breaking when the glass is pressed with sufficient force. One paradigmatic subtype of realizable entities is the concept of dispositions, such as the fragility of a glass and the solubility of salt. Among upper ontologies, Basic Formal Ontology (BFO) features the category of realizable entity, which include dispositions (Arp et al., 2015; Otte et al., 2022) and the Unified Foundational Ontology (UFO) features the category of disposition (Guizzardi, 2005; Guizzardi et al., 2022).

We will develop a "realizable-centered approach to artifacts" in accordance with the aforementioned motivations for an alternative ontology of artifacts. Concerning the motivation from function-based accounts of artifacts, the notion of a realizable entity can be expected to help to develop a more general theory of artifacts (notably, beyond the scope of technical artifacts) than that of function. For one thing, as we will discuss in detail below, various kinds of functions may be generally characterized as subtypes of realizable entities such as dispositions (Roberts, 2024; Röhl & Jansen, 2014; Spear et al., 2016; Toyoshima et al., 2022b; Toyoshima & Jansen, 2026) and there can be correspondingly a group of artifacts that lack functions but have a special kind of realizable entities. This line of approach to artifacts can be found, for example, in Kassel's (2010) theory of artifacts, according to which artifacts have capacities and technical artifacts have functions, which are a subtype of capacities.

Concerning the motivation derived from the intentional dimension of artifacts, we argue that this dimension can be meticulously analyzed through the lens of intention as a realizable entity—specifically, as a disposition. Broadly speaking, an intention, as assumed here, is a disposition to act that comes into being as a result of the interactions between beliefs and desires (Toyoshima et al., 2020). Assuming the dispositional view of intentions, we can provide an ontological analysis (to be elaborated below) of the clay/pot example introduced above: my intention to shape and dry this amount of clay in such a way to be able to contain liquid was realized in my intentional act of shaping and drying the clay to be able to contain liquid.

1.3 Methodology and Scope

To achieve the purpose of developing a realizable-centered approach to artifacts, we will *not* adopt the traditional methodology of addressing the question of what is the correct definition of the term "artifact" as well as what are the correct definitions of domain-neutral artifact-related terms such as "material artifact" and "technical artifact." This is because, like the term "function," the term "artifact" has been employed in very different ways across various domains. As a result, it is doubtful whether seeking a single, universally applicable definition of the term "artifact" across all domains of ontology application would be theoretically and practically valuable (cf. Güngör, 2023, 2026; Preston, 2022b; Sperber, 2007).

We will instead adopt the alternative methodology of introducing two new terms whose ontological analysis can help to understand and formalize different usages of the term "artifact" in different domains: "*canonical artifact*" and "*usefact*." A canonical artifact is an entity that is intentionally produced for a specific purpose. A usefact, by contrast, is an entity intended to be used for some accidental purpose, that is, for a purpose that is different from the one (if any) for which the entity was intentionally produced. Here, we use the term "accidental" without contrasting it with "essential": its usage remains neutral as to the complex relationship between artifacts and essence (Irmak, 2024b; Passinsky, 2024). In particular, a natural object is a usefact when it is intended to be used for any purpose, since it was not intentionally produced for any purpose (or at least, this is the assumption that we make about natural objects throughout this article).

For illustration, when I intentionally shaped and dried this amount of clay in such a way as to be able to contain liquid, the resulting clay pot is a canonical artifact because it is intentionally produced for the purpose of being able to contain liquid. In contrast, when I intend to use a pebble to keep papers in place (cf. Borgo & Vieu, 2009), this pebble is a usefact because it is intended to be used for the accidental purpose of keeping papers in place, or more particularly, simply because it is a natural object that is intended to be used for some purpose.

Regarding the term "canonical artifact," we introduce it with the understanding that the term "artifact" has traditionally been defined as an entity intentionally produced for a specific purpose (e.g., Hilpinen, 1992). Consequently, any well-developed theory of artifacts typically counts it as an artifact. Thus, an entity that is intentionally produced for a specific purpose can be considered as a canonical form of artifact, or simply as a canonical artifact.

Regarding the neologism "usefact," we acknowledge that it may sound slightly etymologically problematic, as the suffix "-fact" derives from the Latin word "factum," meaning "something *made*." However, in introducing the term "usefact," we draw inspiration from existing neologisms such as "naturefact" in anthropology (Oswalt, 1973, 1976) and "ecofact" in archeology (e.g., Kipfer, 2021, p. 422). To borrow Preston's (2022a) explanations, naturefacts are "naturally occurring objects used intentionally, but without modification, for some purpose," such as a pebble intentionally used to keep papers in place; and ecofacts are "organic or inorganic remains of archaeological significance that have undergone no, or minimal, modification by humans, such as animal bones, stored grain, pollen, charcoal, and the like." They are sometimes discussed in the literature on artifacts and functions to consider the difficulty of demarcating natural objects from artifacts (e.g., Artiga, 2016; Preston, 2022a; Spear et al., 2016). We introduce the notion of a usefact partly because, in some theories of artifacts (e.g., Borgo & Vieu, 2009), the term "artifact" refers to usefacts as well as to canonical artifacts, and partly because it will help to analyze artifact-related terms such as "naturefact" and "ecofact."

More specifically, we will focus on the terms "material canonical artifact" and "material usefact" whose ontological analysis will help us better understand various usages of the term "material artifact." We will define these two terms in terms of the ontology of realizable entities. Here we make some clarificatory remarks on the scope of this paper. First, technical artifacts are a typical subtype of material artifacts and they have been explored in formal ontology (Borgo et al., 2014a). By contrast, our focus lies on material artifacts in general, encompassing both technical and non-technical artifacts, including material artworks such as paintings.

At the same time, we will leave out of scope a detailed analysis of specific kinds of material artifacts. For instance, an in-depth study of material artworks would require an ontological analysis of art (Abell, 2012; Currie, 1989; Dickie, 1969; Dipert, 1993; Hick, 2019; Terrone, 2024; Thomasson, 1999, 2004, 2006; Xhignesse, 2020). Moreover, we will leave for future work the examination of so-called "abstract artifacts" (Friedel, 2021; Irmak, 2021; Reicher, 2022; Terrone, 2023), partly because their analysis will require an ontological analysis of abstract entities (Falguera & Martínez-Vidal, 2020; Friedel, 2021; Moltmann, 2013; Toyoshima & Niki, 2024). Abstract artifacts include repeatable artworks (Davies, 2024; Walter, 2013), musical works (Dodd, 2000; Mikalonytė, 2023), fictional characters (Thomasson, 1999, ch. 3), words (Irmak, 2019), languages (Evnine, 2025), and software (Irmak, 2012).

1.4 Organization of the Paper

The paper is structured as follows. Section 2 offers some preliminary background material. Section 3 develops a realizable-centered approach to artifacts. More concretely, we delineate and illustrate the terms "canonical artifact" and "usefact,"

Material entity (see below)
    Natural object (see below)
    *Material canonical artifact** (see Section 3.3)
    *Material usefact** (see Section 3.4)
Realizable entity (see below)
    Intrinsic disposition (Toyoshima et al., 2022c; see below)
        Intention (Toyoshima et al., 2020; see Section 2.3)
    Extrinsic disposition (Toyoshima et al., 2022c; see below)
        Usefactual realizable entity (Toyoshima et al., 2024b; see Section 3.4)
            Usefactual realized entity (Toyoshima et al., 2024b; see Section 3.5.1)
    *Intentional realizable entity** (see Section 3.2)
        *Novel intentional realizable entity** (see Section 3.3)
    *Novel realizable entity** (see Section 3.3)
Process (see below)
    Occurrent belief (Barton et al., 2018a; Toyoshima et al., 2020; see Section 2.3)
    Occurrent desire (Toyoshima et al., 2020; see Section 2.3)
    Act of trying (see Section 2.3)
        Successful act (see Section 2.3)

Figure 1. A taxonomy of classes used in this article.

and define the terms "material canonical artifact" and "material usefact" from the viewpoint of the ontology of realizable entities. Section 4 examines the relationship between functions and artifacts from a realizable-centered perspective. Section 5 illustrates the flexibility and applicability of our framework through its adaptation to BFO. Section 6 discusses various issues arising from our account of artifacts. Section 7 examines preceding works on artifacts, especially those in the field of formal ontology, *vis-à-vis* our realizable-centered approach to artifacts. Finally, Section 8 concludes the paper and outlines directions for future research.

2 Preliminaries

2.1 General Ontological Framework

We introduce a general ontological framework for our investigation that is largely (if not completely; see Section 2.3) realist in spirit (Smith & Ceusters, 2010) in contradistinction with "epistemic ontologies," especially regarding artifacts (Kassel, 2023). Figure 1 provides a taxonomy of classes used in this article. The taxonomy consists of terms denoting classes that are already well-established in existing upper ontologies and in previous formal-ontological works, including ours. In particular, asterisked classes are attributed to Toyoshima et al. (2024a). For notational clarity, we will occasionally use italics for class or type-level entity names (e.g., "*Material entity*") and bold for particulars or instance-level entity names (e.g., "$\mathbf{clay_1}$"). We will also occasionally use subscripts for entity names (e.g., "BFO:*Function*"). In this taxonomy, a necessary and sufficient condition for a class A to be a subclass of a class B (as indicated by indentation) is that all instances of A are also instances of B.

We will now clarify the terms "material entity," "natural object," "process," and "realizable entity" in the taxonomy. First, the notion of a material entity is widely accepted in upper ontologies, as illustrated by the BFO class *Material entity* and the class *Physical endurant* in the upper ontology "Descriptive Ontology for Linguistic and Cognitive Engineering" (DOLCE; Borgo & Masolo, 2010; Borgo et al., 2022; Masolo et al., 2003; Porello et al., 2025). Examples include an amount of clay, people and screwdrivers. We introduce the class *Natural object* as a subclass of the class *Material entity*, assuming that the term "natural object" can be understood intuitively (see Sections 1.1 and 1.3).

Second, processes and events remain widely discussed in formal ontology. They are very differently characterized by different upper ontologies (Rodrigues & Abel, 2019). In this paper we use the term "process" while remaining neutral regarding the detailed classification of occurrents (perdurants), such as the ontological distinctions between processes, events, and states. Our notion of a process aligns approximately with the BFO class *Process* and the DOLCE class *Perdurant*. Instances include the process of my shaping and drying this amount of clay, as well as the process of my using this pebble to keep papers in place.

Third and most importantly, the notion of a realizable entity has been explored in formal ontology, especially in connection with the BFO category of realizable entity (Rabenberg et al., 2024; Röhl & Jansen, 2014). In this paper we will draw upon Toyoshima et al.'s (2022c) framework for realizable entities that is theoretically underpinned by McKitrick's (2018) dispositional pluralism. The basic idea is that realizable entities can be generally understood as dispositions in McKitrick's broad sense of the term.

In particular, we will deploy the notions of an *intrinsic disposition* and an *extrinsic disposition* (McKitrick, 2003; McKitrick, 2018, ch. 8; Vetter, 2015, chs. 4.4–4.5) to specify important subclasses of the class *Realizable entity*. An intrinsic disposition is a realizable entity that is borne purely in virtue of the way the bearer is, for example, in virtue of the internal (physical) structure of the bearer. An extrinsic disposition is a realizable entity that is borne, at least partially, in virtue of the way the world that is external to the bearer is.

Classical examples include the intrinsic disposition of fragility and the extrinsic disposition $\mathbf{d_{ext}}$ of a particular key ($\mathbf{key_a}$) to open a particular lock ($\mathbf{lock_b}$). If $\mathbf{lock_b}$ is annihilated and ceases to exist, $\mathbf{d_{ext}}$ also ceases to exist, even without any physical changes of $\mathbf{key_a}$, because $\mathbf{key_a}$ bears $\mathbf{d_{ext}}$ in virtue of the existence of $\mathbf{lock_b}$, which is external to $\mathbf{key_a}$. Our notion of an intrinsic disposition corresponds to the BFO class *Disposition* and the UFO class *Disposition*, as the former class is described by BFO as an "internally grounded realizable entity" (Toyoshima et al., 2022c; see also Section 5.1.1) and the latter is a subclass of the UFO class *Intrinsic moment*.

2.2 Diachronic Identity in Production and Use

We will outline three philosophical views of diachronic identity as they are crucial for understanding the distinction between production and use, and thus between canonical artifacts and usefacts: the continuity view, the discontinuity view and the constitution view (the latter two grouped under the non-continuity view for expository purposes). We will illustrate them with two examples related to production and use, referred to as "Example A" and "Example B," respectively (see Section 3 for a detailed discussion about the notions of production and use).

Before presenting Examples A and B, we offer a preliminary remark on the usages of the terms "pot" and "paperweight" as they appear in these examples. We assume that the pot in Example A is a canonical artifact (to wit, a material entity intentionally produced for the purpose of being able to contain liquid) and that the paperweight in Example B is a usefact (to wit, a material entity that is intended be used for the accidental purpose of keeping papers in place). Throughout the paper, however, we employ domain-specific artifact-related terms such as "pot" and "paperweight" primarily for illustrative purposes, highlighting our realizable-centered approach to artifacts. A meticulous analysis of these terms would require careful consideration of the difference between "artifact kind(s)" and "(specific) kinds of artifacts" (Irmak, 2024b; Jansen, 2013; Juvshik, 2025; Koslicki & Massin, 2025). As a matter of fact, the term "paperweight" may sometimes refer to a canonical artifact (to wit, a material entity that is intentionally produced for the purpose of keeping papers in place), as is shown by decorated paperweights found in souvenir shops. For this reason, we will provide *fiat* definitions of domain-specific artifact-related terms, whenever appropriate.

We will present Example A (diachronic identity and production) and Example B (diachronic identity and use), in which the terms "pot" and "paperweight" are employed as just explained, respectively:

Example A (diachronic identity and production)**.** *At time t_1, a particular amount of clay ($\mathbf{clay_1}$) is intentionally shaped and dried to be able to contain liquid.*

- *Continuity view: At time t_1, $\mathbf{clay_1}$ continues to exist and comes to instantiate the class Pot.*
- *Non-continuity view: At time t_1, a new material entity $\mathbf{pot_1}$ (which instantiates the class Pot) comes into being.*
  - *Discontinuity view: At time t_1, $\mathbf{clay_1}$ ceases to exist and a new material entity $\mathbf{pot_1}$ comes into being.*
  - *Constitution view: At time t_1, $\mathbf{clay_1}$ continues to exist and a new material entity $\mathbf{pot_1}$ (constituted by, but distinct from, $\mathbf{clay_1}$) comes into being.*

Example B (diachronic identity and use)**.** *At time t_2, a particular pebble ($\mathbf{pebble_2}$) is intended to be used to keep papers in place.*

- *Continuity view: At time t_2, $\mathbf{pebble_2}$ continues to exist and comes to instantiate the class Paperweight.*
- *Non-continuity view: At time t_2, a new material entity $\mathbf{paperweight_2}$ (which instantiates the class Paperweight) comes into being.*
  - *Discontinuity view: At time t_2, $\mathbf{pebble_2}$ ceases to exist and a new material entity $\mathbf{paperweight_2}$ comes into being.*
  - *Constitution view: At time t_2, $\mathbf{pebble_2}$ continues to exist and a new material entity $\mathbf{paperweight_2}$ (constituted by, but distinct from, $\mathbf{pebble_2}$) comes into being.*

We will articulate two different approaches to production and use from the perspective of diachronic identity: the "*monolithic approach*" and "*hybrid approach*." The monolithic approach adopts the same philosophical view of diachronic identity for both production and use. Its strength lies in providing a philosophically coherent and unified framework for understanding both processes. However, it conflicts with intuitions about production and use—specifically, our tendency to assume the non-continuity view of production and the continuity view of use. For instance, Borgo and Vieu (2009) embrace the monolithic approach by assuming the constitution view of both production and use (see also Vieu et al., 2008). Their position has been criticized for its commitment to the constitution view of use: "it appears to us to be counter-intuitive to consider that a mental act gives birth to a new physical object" (Kassel, 2010, p. 242).

By contrast, the hybrid approach adopts different philosophical views of diachronic identity for production and use. A typical version of this approach combines the non-continuity view of production and the continuity view of use. Its strength lies in aligning well with intuitions about production and use. However, it faces the challenge of developing a philosophically well-founded and unified framework for understanding both processes. The hybrid approach may be implicitly assumed by many existing theories of artifacts, where the term "artifact" refers exclusively to canonical artifacts, and no explicit stance on diachronic identity (with respect to production, use, or both) is taken.

In this paper we adopt the monolithic approach to production and use, ensuring that our realizable-centered approach to artifacts serves as a solid theoretical basis for analyzing production, use, and their ontological distinctions. Specifically, we assume the continuity view of both production and use, acknowledging that this may involve a somewhat counterintuitive usage of the term "production." Later, we will consider how our realizable-centered approach to artifacts can be reformulated under the non-continuity view of production and/or use; more concretely, within Borgo and Vieu's (2009) theory of artifacts espousing the constitution view of both production and use (see Section 7.1). This will show that our approach can be adapted to both the monolithic and the hybrid approaches to production and use, rendering it "foundation-agnostic" (Grüninger & Katsumi, 2019). In other words, it can be integrated into different foundational frameworks, accommodating different philosophical views of diachronic identity with respect to production and use.

2.3 An Ontology of Belief, Desire, and Intention

To analyze carefully the intentional dimension of artifacts, we will introduce an ontology of belief, desire, and intention, drawing on existing formal-ontological studies thereof (Barton et al., 2018a; Biccheri et al., 2020; Hobbs & Gordon, 2010; Toyoshima et al., 2020). First, our ontology of belief, desire, and intention will be limited in scope. For instance, we will not closely examine the representational dimension (intentionality, aboutness) of these mental entities (Biccheri et al., 2020; Mizoguchi & Borgo, 2022, 2025; Sanfilippo, 2021; Toyoshima & Barton, 2024a; Williams, 2019a; Yablo, 2014). Additionally, we will consider intentional acts only insofar as they relate to the development of a realizable-centered approach to artifacts. A comprehensive ontological analysis of actions falls outside the scope of this article (Piñeros Glasscock & Tenenbaum, 2023; Trypuz, 2007).

As for belief and desire, we import the notions of an *occurrent belief* and an *occurrent desire* from Toyoshima et al.'s (2020) dual account of belief and desire. An occurrent belief is a mental process of taking something to be the case (Barton et al., 2018a). An occurrent desire is a mental process of wanting something to be the case. Examples include my occurrent belief (**belief**$_1$) that **clay**$_1$ will be capable of containing liquid when it is suitably shaped and dried; and my occurrent desire (**desire**$_1$) for **clay**$_1$ to be capable of containing liquid. Our notions of an occurrent belief and an occurrent desire would correspond, respectively, to the notions of a "belief state" and a "desire state" as found in existing ontologies of mind (e.g., Ferrario & Oltramari, 2004), as we employ "process" as a generic term for, for example, DOLCE:perdurants in this article (see Section 2.1).

As for intention, we will leverage Toyoshima et al.'s (2020) dispositional theory of intention. Interpreted within our ontological framework, an intention is an intrinsic disposition to act that comes into being as a result of the interactions between occurrent beliefs and occurrent desires.

To further develop the view of intention as an intrinsic "disposition to act," we will enrich it with the ontological analyses of goals by Hobbs & Gordon (2010) and Biccheri et al. (2020). Hobbs & Gordon (2010, p. 62) say: "The key concept in modeling intentional behavior is that of an agent *a* having some eventuality type *e* as a goal." Their term "eventuality" is synonymous with our term "process." Biccheri et al. (2020) formally characterize a goal as an entity that is desired or needed by an agent. By synthesizing these ontological accounts of goals, we will assume that a goal is a process type that is the object of an agent's desire, or more specifically, that comes into being through some occurrent desire. Examples include a process type ($Goal_1$) which comes into being through **desire**$_1$ and whose achievement results in a process of **clay**$_1$ being capable of containing liquid.

This ontological analysis of goals can be further elucidated as follows. First, because of our broad notion of a process (see Section 2.1), our process-based view of goals can be compatible with the existing state-based view thereof (e.g., Borgo

et al., 2016; Mizoguchi et al., 2016). Second, $Goal_1$ is a "particular type," that is, a type that is ontologically dependent on some particular entity such as $\mathbf{clay_1}$ (Brodaric & Grüninger, 2018). Third, a formal representation of $Goal_1$ may warrant consideration from a realist perspective because $Goal_1$ can never be instantiated: a desire-directed goal ceases to exist when it is achieved, and the associated desire is satisfied (see Section 2.1; and also Section 5.2).

We introduce the class *Act of trying* and its subclass *Successful act* under the category of process, corresponding to Hobbs and Gordon's (2010) notions of "trying" and "success," respectively. An act of trying is a process in which an agent attempts to achieve a goal, that is, a process in which the agent strives to bring into existence an instance of that goal (for in-depth discussions on trying, see Grünbaum, 2008; Hornsby, 1980; McCann, 1975; O'Shaughnessy, 1980; Stuchlik, 2013). A successful act, in turn, is an act of trying that results in goal achievement, that is, an act of trying in which some agent does bring into existence an instance of the relevant goal. To clarify the dispositional account of intention, we propose that an intention is an intrinsic disposition to perform an act of *trying* that arising from the interactions between occurrent beliefs and occurrent desires. For simplicity, we will continue to use expressions of the form "intention to V" (where "V" stands for a verb such as "use") rather than the more explicit form "intention to try to V."

To provide a general illustration of our ontology of belief, desire, and intention, suppose that I intended to shape and dry $\mathbf{clay_1}$ to be able to contain liquid. At that time, $\mathbf{intention_1}$ comes into being, where $\mathbf{intention_1}$ is my intention to shape and dry $\mathbf{clay_1}$ in such a way as to be able to contain liquid. We can analyze $\mathbf{intention_1}$ as my intrinsic disposition to perform an act of trying to shape and dry $\mathbf{clay_1}$ that comes into being as a result of the interactions between occurrent beliefs and occurrent desires such as $\mathbf{belief_1}$ and $\mathbf{desire_1}$. Suppose further that I intentionally shaped and dried $\mathbf{clay_1}$ so that it is now capable of containing liquid. At that time, $\mathbf{intention_1}$ is realized in my successful act ($\mathbf{act_1}$) of shaping and drying $\mathbf{clay_1}$ and, with the achievement of $Goal_1$, $\mathbf{act_1}$ has as part a particular process of $\mathbf{clay_1}$ being capable of containing liquid.

3 A Realizable-Centered Approach to Artifacts

3.1 Canonical Artifacts and Usefacts

We introduced the terms "canonical artifact" and "usefact" in Section 1.3. A canonical artifact is an entity that is intentionally produced for a specific purpose. A usefact is an entity that is intended to be used for some accidental purpose, i.e., for some purpose that is different from the one (if any) for which the entity was intentionally produced (cf. Evnine's (2022) "counter-use"). We will further elucidate the notions of a canonical artifact and a usefact by illustrating them with four examples involving material entities.

Example 1 (canonical artifact)**.** *At time t_1, a particular amount of clay ($\mathbf{clay_1}$) is intentionally shaped and dried to be able to contain liquid.*

In this example, $\mathbf{clay_1}$ at time t_1 is a canonical artifact because it is intentionally shaped and dried for the purpose of being able to contain liquid. Assume that the term "pot" is defined as: "A material entity that is intentionally produced for the purpose of being able to contain liquid." Under the continuity view of production (which may involve some counterintuitiveness; see Section 2.2), the production of a canonical artifact at time t_1 is explicable by $\mathbf{clay_1}$ instantiating the class *Pot* at time t_1.

We now address the choice of Example 1 as a driving example of canonical artifacts. Some may view the clay example as a simplistic or toy example of canonical artifacts and prefer to consider practical examples of complex canonical artifacts, such as screwdrivers and cars, as found in the industry domain; cf. Houkes and Vermaas's (2009a) critique of the "artisan model" of artifacts. Nevertheless, we chose to illustrate canonical artifacts with this simple example. Indeed, complex canonical artifacts involve the aggregation of a multiplicity of diverse parts and their ontological analysis would require an in-depth study of their structure (Grüninger et al., 2020; Koslicki, 2008), in particular their features and components (Sanfilippo et al., 2016). This may call for a non-standard mereology, whose study extends beyond the scope of this paper (see Masolo et al., 2020 for a formal analysis of composition and Section 8 for a pointer to future inquiry).

Example 2 (usefact and natural object)**.** *At time t_2, a particular pebble ($\mathbf{pebble_2}$) is intended to be used to keep papers in place.*

In this example, $\mathbf{pebble_2}$ at time t_2 is a usefact because it is intended to be used for the accidental purpose of keeping papers in place, or more simply, because it is a natural object that is intended to be used for some purpose (see Section 1.3). Assume that the term "paperweight" is defined as follows: "A material entity that is intended to be used for the accidental purpose of keeping papers in place." Under the continuity view of use, $\mathbf{pebble_2}$ being intended to be used in this way at time t_2 can be analyzed as $\mathbf{pebble_2}$ instantiating the class *Paperweight* at time t_2.

A few clarificatory remarks concerning Example 2 are in order. First, the expression "be intended to be used to do" is employed throughout the paper independently of whether it is *actually* used for that purpose. The distinction between use intention (even without associated actual use) and actual use has been highlighted by Borgo and Vieu (2009) and Toyoshima et al. (2022b).

We characterize the notion of a usefact in terms of use intention rather than actual use. This offers two key advantages. Firstly, it helps to understand a wide range of theories of artifacts, including Borgo and Vieu's (2009) theory, according to which $\mathbf{pebble_2}$ at time t_2 is an artifact (see Section 7.1). Secondly, it enables a clear, realizable-based distinction between canonical artifacts and usefacts (see Sections 3.3 and 3.4). Consequently, our notion of a usefact is broader than the anthropological notion of a naturefact, as the latter is associated with actual use (see Sections 1.1 and 3.5.1).

Second, there are at least two different, broad and narrow, senses of the term "use" in relation with production. According to the broad interpretation, production is a kind of use, as is illustrated by Houkes and Vermaas's (2010, 2014) statement that a "make plan" is a kind of "use plan" (see Section 7.2.2 for details). According to the narrow interpretation, use is distinct from production. In this article, we adopt the narrow interpretation of "use" to maintain a sharp distinction between canonical artifacts and usefacts. However, we will also investigate a type of use closely linked to production—aligning roughly with the broad interpretation—under the term "use for production" in Section 6.3.

Example 3 (usefact and canonical artifact)**.** *At time t_1' (later than time t_1), $\mathbf{clay_1}$ is intended to be used to hold a door open.*

In this example, $\mathbf{clay_1}$ at time t_1' remains a canonical artifact after having become so at time t_1. Simultaneously, it is also a usefact because it is intended to be used for the accidental purpose of holding a door open, which is different from the purpose for which the canonical artifact $\mathbf{clay_1}$ was intentionally produced (in the sense of the continuity view) at time t_1, i.e., the purpose of being able to contain liquid. Assume that the term "doorstop" is defined as follows: "A material entity that is intended to be used for the accidental purpose of holding a door open." Under the continuity view of use, the usefact $\mathbf{clay_1}$ being intended to be used in this way at time t_1' is explicable by $\mathbf{clay_1}$ instantiating the class *Doorstop* at time t_1'.

Example 4 (properly used canonical artifact)**.** *At time t_1" (later than time t_1), $\mathbf{clay_1}$ is intended to be used to contain liquid.*

In this example, $\mathbf{clay_1}$ at time t_1" continues to be a canonical artifact after having become so at time t_1. Contrary to $\mathbf{clay_1}$ at time t_1', it is not a usefact because it is intended to be used for the purpose of containing liquid and this purpose is not accidental, as it is the same as the purpose for which the canonical artifact $\mathbf{clay_1}$ was intentionally produced (in the sense of the continuity view) at time t_1, i.e., the purpose of being able to contain liquid. Informally speaking, the canonical artifact $\mathbf{clay_1}$ is properly used at time t_1" but it is not a usefact anymore.

3.2 Intentional Realizable Entity

We will analyze the notions of a canonical artifact and a usefact in terms of the ontology of realizable entities. More specifically, we will provide a realizable-based definition of the terms "material canonical artifact" and "material usefact." Let us first consider the canonical artifact $\mathbf{clay_1}$ at time t_1. We will focus on the intrinsic disposition $\mathbf{d_1}$ that $\mathbf{clay_1}$ comes to bear at time t_1 purely in virtue of its specific physical (e.g., container-like) structure (see Section 6.1 for the fundamental issue of the individuation of realizable entities; and we will not repeat this point in introducing realizable entities below).

We propose to analyze the canonical artifact $\mathbf{clay_1}$ at time t_1 in terms of the intrinsic disposition $\mathbf{d_1}$; in particular, its intentional dimension can be understood in terms of two distinctive features of $\mathbf{d_1}$. To this end, we will reintroduce the following particular entities, based on the discussion in Section 2.3:

- $\mathbf{belief_1}$: my occurrent belief that $\mathbf{clay_1}$ will be capable of containing liquid when it is suitably shaped and dried.
- $\mathbf{desire_1}$: my occurrent desire that $\mathbf{clay_1}$ should be capable of containing liquid.
- $Goal_1$: a process type that comes into being through $\mathbf{desire_1}$ and whose achievement results in a process of $\mathbf{clay_1}$ being capable of containing liquid.
- $\mathbf{intention_1}$: my intrinsic disposition to perform an act of trying to shape and dry $\mathbf{clay_1}$ that comes into being as a result of the interactions between occurrent beliefs and occurrent desires such as $\mathbf{belief_1}$ and $\mathbf{desire_1}$.
- $\mathbf{act_1}$: my successful act of shaping and drying $\mathbf{clay_1}$ which has as part a process of $\mathbf{clay_1}$ being capable of containing liquid, occurring with the achievement of $Goal_1$.

First, $\mathbf{d_1}$ comes into being through an intentional act, as it comes into being through $\mathbf{act_1}$ and $\mathbf{act_1}$ is a realization of $\mathbf{intention_1}$. Second, a realization of $\mathbf{d_1}$ is determined by an associated goal (i.e., $Goal_1$) in the sense that the former is a process of $\mathbf{clay_1}$ containing liquid and an instance of the latter is a process of $\mathbf{clay_1}$ being capable of containing liquid. In light of these observations, we define the term "intentional realizable entity" as follows[2]:

Definition 1 (intentional realizable entity)**.** *intentional realizable entity* $=_{\text{def.}}$ *A realizable entity (i) that comes into being through an intentional act and (ii) whose realization is determined by an associated goal.*

By this definition, $\mathbf{d_1}$ (borne by $\mathbf{clay_1}$ at time t_1) is an intentional realizable entity.

Definition 1 can be further clarified as follows. First, this definition, especially item (ii), implies a close connection between intentional realizable entities and goals. However, this should not be conflated with the statement that any realizable entity is goal-directed in the sense that it is directed toward some associated type of processes (Tugby, 2024). We employ the term "goal" in the intentional sense of the term in this paper (see Section 2.3). For instance, the intrinsic disposition of uranium to decay is goal-directed in the broad, non-intentional sense of the term; but it is not goal-directed in the narrow, intentional sense of the term, since uranium can decay naturally without human intervention.

Relatedly, we will use the term "goal" rather than "purpose" when characterizing intentional realizable entities to encompass a wider range of canonical artifacts, extending beyond technical artifacts. For instance, McKitrick (2024) defines "artificial disposition" as "the disposition[s] that human beings deliberately cause something to have, in order to serve some purpose," in alignment with her dispositional pluralism, which underpins our ontology of realizable entities (see Section 2.1). While our notion of an intentional realizable entity can be linked to McKitrick's notion of an artificial disposition, it is intended to be more general (for an illustration, see our analysis of Koslicki & Massin's (2025) "placebo capacity" in terms of intentional realizable entities in Section 3.5.2).

Second, one may argue that the term "intentional act" in Definition 1 is generally susceptible to a wide interpretation (cf. Borgo et al.'s (2014a) taxonomy of actions) and must be here interpreted in a constrained way in order to characterize the notion of a canonical artifact. For example, one may claim that intentional acts should involve physical modifications (e.g., shaping and drying).

On the contrary, we suggest that the term "intentional act" in the definition should be construed broadly enough to accommodate "mental selection" (cf. Borgo & Vieu, 2009). This broad understanding is motivated by the idea that, while physical modification has been a standard criterion for the production of artifacts (cf. Preston, 2022a; see also Section 7.2), the production of some kind of canonical artifacts may be better explained in terms of the notion of "appropriation" figuring in philosophy of artifacts (Hilpinen, 1992; Juvshik, 2021a; Preston, 2013, pp. 96–103; Thomasson, 2014). Examples of such canonical artifacts include ready-made artworks (e.g., Marcel Duchamp's *Fountain*; see also Evnine, 2013), where "appropriation" refers roughly to an intentional act of making an artwork from some pre-existing entity (or entities) with little or no physical modification (e.g., signing a urinal). Insofar as material artifacts are concerned, the philosophical notion of appropriation can be construed within our framework as an intentional act in which a material entity becomes a canonical artifact through little or no physical modification. We will delve into this point in Section 3.3.

Third, one might consider simplifying Definition 1 by omitting item (ii): "intentional realizable entity $=_{\text{def.}}$ A realizable entity that comes into being through an intentional act." While this simpler definition might seem sufficient to capture the intentional dimension of canonical artifacts, it would fail to distinguish canonical artifacts from so-called "by-products": roughly, unintended or purposeless outcomes of production processes. Although a full-fledged ontological analysis of products falls outside the scope of this paper (Vignolo, 2010a, 2010b), the notion of a by-product is used in domain ontologies, as is witnessed by class terms such as *Poultry by-product* (http://purl.obolibrary.org/obo/FOODON_00004144) in FoodOn, a BFO-compliant ontology of food and food production (Dooley et al., 2018).

To illustrate, consider a classical example of a by-product (e.g., Preston, 2022a): when sawdust is unintentionally produced during a woodworking operation and, by hypothesis, lacks any intended purpose, its combustibility is not an intentional realizable entity according to Definition 1. However, under some interpretation of the simpler definition, it could implausibly count as an intentional realizable entity, as the woodworking operation is an intentional act.

Fourth and finally, one may argue that the terms "is determined by" and "an associated goal" in Definition 1 should be construed in a suitably restrictive manner. While the terms "determined" and "associated" may be difficult to characterize generally, they can be elucidated with examples.[3] We propose that these terms should be understood widely enough to encompass a wide range of canonical artifacts, extending beyond technical artifacts. In particular, regarding the term "associated," consider the analysis of Example 1: $Goal_1$ is directly associated with $\mathbf{act_1}$, as $\mathbf{desire_1}$ (through which $Goal_1$ comes into being) and $\mathbf{intention_1}$ (realized in $\mathbf{act_1}$) both involve the idea of $\mathbf{clay_1}$ becoming capable of containing liquid. However, the association between intentional acts and goals may be more indirect when it comes to non-technical artifacts. We will illustrate this point with Koslicki and Massin's (2025) notion of a "faith-based artifact" in Section 3.5.2.

3.3 Material Canonical Artifacts and Novel Intentional Realizable Entities

We introduced in Section 3.2 the term "intentional realizable entity" to analyze canonical artifacts, particularly their intentional dimension. One may attempt to define a "material canonical artifact" as "a material entity that bears an intentional realizable entity." However, in our view, while bearing an intentional realizable entity is a necessary condition for a material entity to be a canonical artifact, it is not sufficient. This is because material usefacts can also bear intentional realizable entities.

To illustrate, consider Example 2: at time t_2, **pebble$_2$** is intended to be used to keep papers in place. We will focus on two realizable entities involved in this example. One is the intention (**intention$_2$**) to use **pebble$_2$** to keep papers in place that comes into being at time t_2, where **intention$_2$** is an intrinsic disposition. The other is the extrinsic disposition **d$_2$** of **pebble$_2$** to keep papers in place that comes into being at time t_2, where **d$_2$** is an extrinsic disposition, as **pebble$_2$** bears **d$_2$** in virtue of the existence of **intention$_2$**, external to **pebble$_2$**. Such an extrinsic disposition can be understood within existing foundational frameworks, such as a role in BFO (see Section 5). Furthermore, we can justify the existence of **d$_2$** using a Borgo and Vieu's (2009) analysis of Example 1: at time t_2, **pebble$_2$** is "mentally selected" to keep papers in place, and simultaneously, the "attributed capacity" to keep papers comes to inhere in a new material entity **paperweight$_2$** which is constituted by **pebble$_2$** (see Section 7.1 for details on Borgo & Vieu's theory of artifacts).

According to Definition 1, **d$_2$** is an intentional realizable entity for two reasons. First, **d$_2$** comes into being through the intentional act of mental selection. Second, a realization of **d$_2$** is a process of **pebble$_2$** keeping papers in place and it is determined by a goal associated with the intentional act of mental selection (e.g., a process type whose achievement results in a process of **pebble$_2$** keeping papers in place). Therefore, both the intrinsic disposition **d$_1$** (borne by **clay$_1$** at time t_1) and the extrinsic disposition **d$_2$** (borne by **pebble$_2$** at time t_2) are intentional realizable entities. Nonetheless, **clay$_1$** at time t_1 is a canonical artifact, whereas **pebble$_2$** at time t_2 is a usefact. To summarize, defining "material canonical artifact" as "a material entity that bears an intentional realizable entity" is implausible, as material usefacts serve as counterexamples.

More generally, the mere fact that a material entity bears an intentional realizable entity fails to distinguish canonical artifacts from usefacts. Arguably, this is because it fails to capture the ontological difference between production and use: a canonical artifact is an entity intentionally *produced* for a specific purpose, whereas a usefact is an entity intended to be *used* for some accidental purpose.

In our view, the notion of *novelty* of a realizable entity can serve to specify the distinction between production and use, as well as between canonical artifacts and usefacts. To elaborate, we will focus on the *intrinsic* disposition **d$_2$'** of **pebble$_2$** to keep papers in place (to be explained in more detail) in contradistinction with the *extrinsic* disposition **d$_2$** of **pebble$_2$** to keep papers in place, which comes into being at time t_2 (as previously introduced).

On the one hand, **d$_2$'** is an intrinsic disposition, as **pebble$_2$** bears **d$_2$'** purely in virtue of its specific physical structure (e.g., its solidity). Furthermore, **d$_2$'** can exist even in the absence of any associated use intentions, such as **intention$_2$**. In particular, **d$_2$'** exists before time t_2, when **intention$_2$** comes into being. Therefore, **d$_2$'** is not an intentional realizable entity because it does not come into being through an intentional act.

On the other hand, **d$_2$** is an extrinsic disposition, as **pebble$_2$** bears **d$_2$** in virtue of the existence of **intention$_2$**, external to **pebble$_2$**. Specifically, **d$_2$** comes into being at time t_2 and ceases to exist when **intention$_2$** ceases to exist, even without any physical changes of **pebble$_2$**. As previously established, **d$_2$** is an intentional realizable entity.

Despite these ontological differences, **d$_2$** and **d$_2$'** are intimately connected: whenever **d$_2$** is realized in a particular process, **d$_2$'** is also realized in the same process. To put it differently, **d$_2$** is not a "novel" realizable entity for its bearer **pebble$_2$** in the sense that any realization of **d$_2$** is also a realization of **d$_2$'**, which exists *before* **d$_2$** comes into being. At time t_2, **pebble$_2$** comes to bear **d$_2$** and **d$_2$** is an intentional realizable entity. However, **pebble$_2$** does not become a canonical artifact at time t_2; rather, it becomes a usefact, due to the "non-novelty" of **d$_2$** for its bearer **pebble$_2$**.

Let us now compare the intrinsic disposition **d$_1$** of **clay$_1$** to contain liquid, which comes into being at time t_1, with the extrinsic disposition **d$_2$** of **pebble$_2$** to keep papers in place, which comes into being at time t_2. Although both **d$_1$** and **d$_2$** are intentional realizable entities, **clay$_1$** at time t_1 (unlike **pebble$_2$** at time t_2) does not bear any realizable entities that existed before **d$_1$** came into being and that would be realized in the same processes in which **d$_1$** is realized. Unlike **d$_2$**, **d$_1$** is an intentional realizable entity whose realization is of a "new" kind for its bearer **clay$_1$**. At time t_1, **clay$_1$** is a canonical artifact in virtue of bearing **d$_1$**, because **d$_1$** is an intentional realizable entity that is "novel" for its bearer **clay$_1$**.

To spell out the idea of the "novelty" of intentional realizable entities involved in canonical artifacts, we introduce the terms "novel realizable entity" and "novel intentional realizable entity" as follows[4]:

Definition 2 (novel realizable entity)**.** *novel realizable entity* $=_{\text{def.}}$ *A realizable entity r such that its bearer has no realizable entity r' where (i) r' exists before r comes into being and (ii) if r is realized in a process, then r' is realized in the same process.*

Definition 3 (novel intentional realizable entity)**.** *novel intentional realizable entity* $=_{\text{def.}}$ *An intentional realizable entity that is a novel realizable entity.*

By these definitions, $\mathbf{d_1}$ is a novel intentional realizable entity, whereas $\mathbf{d_2}$ is not a novel realizable entity owing to $\mathbf{d_2}$**'** and consequently is not a novel intentional realizable entity. We can now define the term "material canonical artifact" in terms of the notion of a novel intentional realizable entity as follows:

Definition 4 (material canonical artifact)**.** *material canonical artifact* $=_{\text{def.}}$ *A material entity that bears a novel intentional realizable entity.*

By this definition, $\mathbf{clay_1}$ at time t_1 (as well as at times t_1' and t_1") is a material canonical artifact in virtue of bearing the novel intentional realizable entity $\mathbf{d_1}$. In contrast, $\mathbf{pebble_2}$ at time t_1' is not a material canonical artifact, despite bearing the intentional realizable entity $\mathbf{d_2}$, as $\mathbf{d_2}$ is not a novel realizable entity.

We offer some clarificatory remarks on the argumentation developed so far, including Definitions 2–4. First, our characterization of production in terms of novel realizable entities is based on Definition 4: the production of the canonical artifact $\mathbf{clay_1}$ at time t_1 corresponds to the novel (and intentional) realizable entity $\mathbf{d_1}$ coming into being at that time. However, our realizable-based approach to production rests on comparing the realizations of two different realizable entities, or more specifically, on the identity of the relevant realizations, which are processes, as is explicitly indicated by item (ii) of Definition 2. We will discuss the foundational topic of the identity of processes in Section 6.2.

Second, our analysis of Example 2 (usefact and natural object) can be applied, *mutatis mutandis*, to Example 3 (usefact and canonical artifact). In the latter example, consider the extrinsic disposition $\mathbf{d_3}$ of $\mathbf{clay_1}$ to hold a door open, which comes into being at time t_1' and the intrinsic disposition $\mathbf{d_3}$**'** of $\mathbf{clay_1}$ to hold a door open, which comes into being at and continues to exist after time t_1. On the one hand, $\mathbf{d_3}$ is an extrinsic disposition, as $\mathbf{clay_1}$ bears $\mathbf{d_3}$ in virtue of the existence of the intention to use $\mathbf{clay_1}$ to hold a door open, which is external to $\mathbf{clay_1}$. On the other hand, $\mathbf{d_3}$**'** is an intrinsic disposition, as $\mathbf{clay_1}$ bears $\mathbf{d_3}$**'** purely in virtue of its specific physical structure (e.g., its solidity). According to Definitions 2–4, $\mathbf{clay_1}$ does not become a material canonical artifact at time t_1' because $\mathbf{d_3}$ is not a novel realizable entity due to the existence of $\mathbf{d_3}$**'** and thus is not a novel intentional realizable entity. Instead, $\mathbf{clay_1}$ continues to be a material canonical artifact after time t_1 because it continues to bear the novel intentional realizable entity $\mathbf{d_1}$ after that time.

Third, we propose to characterize canonical artifacts in terms of novel intentional *realizable entities*, rather than novel intentional *intrinsic dispositions*, even though $\mathbf{d_1}$—featured in our driving example of canonical artifacts (Example 1)—is a novel intentional intrinsic disposition. This broader approach is motivated by the need to accommodate a wider range of artifacts beyond technical artifacts, even though many kinds of technical artifacts may indeed be characterized in terms of novel intentional intrinsic dispositions.

In the context of material artifacts, for instance, the philosophical notion of appropriation (see Section 3.2) can be understood within our framework as an intentional act in which a material entity becomes a canonical artifact in virtue of bearing a novel intentional *extrinsic disposition*. This is because acquiring an extrinsic disposition does not necessarily involve physical changes of the material entity that bears it. We will further illustrate novel intentional extrinsic dispositions with Koslicki and Massin's (2025) notion of a placebo capacity in Section 3.5.2.

Fourth and finally, it is important to examine whether our realizable-centered analysis of canonical artifacts—developed under the continuity view of both production and use—can be reconstructed under the non-continuity view of production and/or use (see Section 2.2). To address this, we need to consider how Definition 1 (intentional realizable entity) and Definition 2 (novel realizable entity) can hold under the non-continuity view of production and/or use.

Regarding Definition 1, it is straightforward to adapt this definition to both the non-continuity view of production and the non-continuity view of use. In particular, with respect to item (i) in the definition, if a realizable entity comes into being through an intentional act under the continuity view of production (or use), this condition is trivially satisfied under the non-continuity view of production (or use).

Regarding Definition 2, we will defer the question of how it can hold under the non-continuity view of production and/or use, as the answer depends on the specific details of the endorsed non-continuity view of production (or use), including whether it is the discontinuity view or the constitution view of production (or use). We will address this issue in Section 7.1 in discussing Borgo and Vieu's (2009) theory of artifacts which is committed to the constitution view of both production and use.[5]

3.4 Material Usefacts and a Special Kind of Non-Novel Intentional Realizable Entities

We now turn to a close examination of the notion of a usefact. We will define the term "material usefact" based on the realizable-based definition of "material canonical artifact" (Definition 4) provided in Section 3.3. A naïve attempt might

define this term as "a material entity that bears an intentional realizable entity that is not a novel realizable entity," or more simply as "a material entity that bears a non-novel intentional realizable entity," where the term "non-novel realizable entity" is defined as "a realizable entity that is not a novel realizable entity." This naïve definition would correctly classify **pebble$_2$** at time t_1' as a material usefact, given that it bears **d$_2$**, a non-novel intentional realizable entity.

However, this naïve definition may be too broad. To illustrate, consider Example 4: at time t_1" (later than time t_1), **clay$_1$** is intended to be used to contain liquid. Let us focus on the extrinsic disposition **d$_4$** of **clay$_1$** to contain liquid, which comes into being at time t_1". We can justify the existence of **d$_4$** in the same way we justified the existence of the extrinsic disposition **d$_2$** of **pebble$_2$** to keep papers in place in Example 2, drawing on Borgo and Vieu's (2009) theory of artifacts (see Section 3.3). Like **d$_2$**, **d$_4$** is a non-novel intentional realizable entity. In particular, **d$_4$** is non-novel because if **d$_4$** is realized in a process, then the intrinsic disposition **d$_1$** of **clay$_1$** to contain liquid (which comes into being at time t_1) is realized in the same process. According to the naïve definition, **clay$_1$** at time t_1" would be a material usefact in virtue of bearing the non-novel intentional realizable entity **d$_4$**. However, this would contradict our notion of a usefact as an entity that is intended to be used for an *accidental* purpose, that is, a purpose different from the one (if any) for which the entity was intentionally produced.

Therefore, usefacts should be considered as material entities that bear a specific kind of non-novel intentional realizable entities. To this end, we introduce the relation of "being non-novel because of" between two realizable entities, based on Definition 2 (novel realizable entity), as follows:[6]

Definition 5 (is non-novel because of)**.** *A realizable entity r is non-novel because of a realizable entity r'* $=_{\text{def.}}$ *There exists some bearer b such that (i) b bears r and (ii) b bears r' and (iii) r' exists before r comes into being and (iv) if r is realized in a process, then r' is realized in the same process.*

This definition enables us to classify non-novel intentional realizable entities (such as **d$_2$**, **d$_3$** and **d$_4$**) into two types:

- Non-novel because of some novel intentional realizable entity
  The extrinsic disposition **d$_4$** of **clay$_1$** to contain liquid is non-novel because of the intrinsic disposition **d$_1$** of **clay$_1$** to contain liquid, where **d$_1$** is both novel and intentional (Example 4; at time t_1").
- Non-novel because of some realizable entity that is not a novel intentional realizable entity
  The extrinsic disposition **d$_2$** of **pebble$_2$** to keep papers in place is non-novel because of the intrinsic disposition **d$_2$'** of **pebble$_2$** to keep papers in place, where **d$_2$'** is not intentional and thus not a novel intentional realizable entity (Example 2; at time t_2).
  The extrinsic disposition **d$_3$** of **clay$_1$** to hold a door open is non-novel because of the intrinsic disposition **d$_3$'** of **clay$_1$** to hold a door open, where **d$_3$'** is not intentional and thus not a novel intentional realizable entity (Example 3; at time t_1').

Given that material usefacts can be characterized in terms of bearing the second type of non-novel intentional realizable entities, we define the term "material usefact" as follows:

Definition 6 (material usefact)**.** *material usefact* $=_{\text{def.}}$ *A material entity that bears an intentional realizable entity which is non-novel because of some realizable entity that is not a novel intentional realizable entity.*

By this definition, **pebble$_2$** at time t_2 is a material usefact in virtue of bearing **d$_2$** and **clay$_1$** at time t_1' is a material usefact in virtue of bearing **d$_3$**. However, **clay$_1$** at time t_1" is not a material usefact, despite bearing **d$_4$**.

We remark that Definition 6 could be simplified as follows. An alternative approach would be to first define the term "usefactual realizable entity" as follows:[7]

Definition 7 (usefactual realizable entity)**.** *usefactual realizable entity* $=_{\text{def.}}$ *An intentional realizable entity that is non-novel because of some realizable entity that is not a novel intentional realizable entity.*

By this definition, **d$_2$** (borne by **pebble$_2$** at time t_2) and **d$_3$** (borne by **clay$_1$** at time t_1') are usefactual realizable entities. We note that usefactual realizable entities are a subtype of extrinsic dispositions because any usefactual realizable entity is borne by its bearer in virtue of the existence of some intention to use the bearer for some purpose, and this use intention is external to the bearer. This allows us to provide a simpler definition of the term "material usefact" in terms of the notion of a usefactual realizable entity as follows:

Definition 8 (material usefact)**.** *material usefact* $=_{\text{def.}}$ *A material entity that bears a usefactual realizable entity.*

By this definition (as well as by Definition 6), **pebble$_2$** at time t_2 and **clay$_1$** at time t_1' are material usefacts.

3.5 Theoretical Application

To illustrate the theoretical applications of our realizable-centered approach to artifacts, we will analyze two kinds of entities discussed in the literature: naturefacts in anthropology (Section 3.5.1) and faith-based artifacts in Koslicki & Massin's (2025) account of artifacts (Section 3.5.2).

3.5.1 Naturefact. As mentioned in Section 1.3, the term "naturefact" in anthropology refers to "naturally occurring objects used intentionally, but without modification, for some purpose" (Preston, 2022a). In Section 3.1, we argued that our notion of a usefact is broader than the anthropological notion of a naturefact: the latter is restricted to natural objects and is characterized in terms of actual use, whereas the former is defined in terms of use intention.

In light of our analysis of material usefacts in Section 3.4, we will provide a realizable-based definition of the term "naturefact." In actual anthropological practice, the term "naturefact" refers to a natural object *that was or is* used intentionally, but without modification, for some purpose. Given the complexity of the temporal dimension in this original notion, we will focus on a simplified version: a naturefact as a natural object *that is being* used intentionally, but without modification, for some purpose.

To illustrate, let us introduce the following example, based on Example 2 (usefact and natural object):

Example 5 (naturefact)**.** *At time t_2' (later than time t_2),* ***pebble$_2$*** *is intentionally used to keep papers in place.*

In this example, **pebble$_2$** at time t_2' is a naturefact, as it is a natural object intentionally used to keep papers in place.

We will characterize naturefacts (in the simplified sense) as a special kind of material usefacts. To illustrate the basic idea with Example 5, **pebble$_2$** continues to bear after time t_2, and bears at time t_2', the extrinsic disposition **d$_2$** to keep papers in place and **d$_2$** is a usefactual realizable entity (see Section 3.4, especially Definition 7). The intentional use of the naturefact **pebble$_2$** at time t_2' can be explained by **d$_2$** being realized at that time, since a realization of **d$_2$** is a process of **pebble$_2$** being intentionally used to keep papers in place. Based on this analysis, we introduce the term "usefactual *realized* entity" as follows:

Definition 9 (usefactual realized entity)**.** *usefactual realized entity* $=_{\text{def.}}$ *A usefactual realizable entity that is realized.*

By this definition, **d$_2$** (borne by **pebble$_2$** at time t_2') is a usefactual realized entity. We can now define the term "naturefact" (in the simplified sense) in terms of the notion of a usefactual realized entity:

Definition 10 (naturefact)**.** *naturefact* $=_{\text{def.}}$ *A natural object that bears a usefactual realized entity.*

By this definition, **pebble$_2$** at time t_2' is a naturefact because it is a natural object bearing **d$_2$**. We note that the property of being physically unmodified, which is found in Preston's (2022a) explanation of naturefacts, can be captured by the statement that usefactual realized entities—like usefactual realizable entities in general—are a subtype of extrinsic dispositions. Indeed, bearing an extrinsic disposition does not necessarily involve physical changes of the material entity that bears it.

3.5.2 Faith-Based Artifact. Koslicki and Massin (2025) introduced the term "faith-based artifact" to refer to artifacts that are intended and believed by their creators and users to perform a function they do not actually perform (see Section 4 for our analysis of functions and artifacts). Examples of faith-based artifacts range from religious and ritualistic objects (e.g., amulets and talismans) to abstract artifacts such as theories or ideologies (e.g., conspiracy theories).

Koslicki and Massin suggest that faith-based artifacts can be analyzed using their notion of a "placebo capacity": roughly, a capacity to subjectively (but not objectively) satisfy an agent's desire to produce the relevant effect in the presence of her belief that the entity can bring about this effect. For instance, an amulet can be ascribed the placebo capacity to subjectively satisfy the user's desire to dispel evil spirits in the presence of the relevant belief on the part of the agent that it can in fact dispel evil spirits. However, since amulets lack the capacity to dispel evil spirits, the user's desire can only be subjectively, but not objectively, satisfied.

We will analyze the notions of a faith-based artifact and a placebo capacity within our realizable-centered framework, focusing on material artifacts. To this end, we make two clarifying assumptions. First, we assume that if a material entity is a faith-based artifact, then it bears a placebo capacity, while remaining agnostic as to whether the converse holds. Second,

we assume that the intentional dimension of faith-based artifacts stems from some relevant intention. We will not explore the possibility that this dimension might be explicable without recourse to intentions, for example in terms of beliefs and desires alone (as touched upon by Toyoshima et al., 2024a, 2024b), as it would require a substantive reconstruction of our realizable-centered approach to artifacts.

Let us now introduce the following example of faith-based artifacts:

Example 6 (faith-based artifact)**.** *At time t_3, **pebble$_2$** is intended to be used to dispel evil spirits.*

In this example, **pebble$_2$** at time t_3 is a faith-based artifact, as it is intended and believed to be capable of dispelling evil spirits, though it lacks the actual capacity to do so. More precisely, **pebble$_2$** cannot dispel evil spirits because such a process is nomologically impossible, given our knowledge of the laws of nature in our actual world.

To analyze the intentional dimension of **pebble$_2$** at time t_3, we introduce the mental entities that are involved in Example 6:

- **belief$_2$**: my occurrent belief that **pebble$_2$** can dispel evil spirits.
- **desire$_2$**: my occurrent desire for **pebble$_2$** to dispel evil spirits.
- **intention$_3$**: my intrinsic disposition to perform an act of trying to use **pebble$_2$** to dispel evil spirits which comes into being at time t_3 as a result of interactions between occurrent beliefs and occurrent desires, such as **belief$_2$** and **desire$_2$**.

We can justify the existence of **intention$_3$** on the grounds that, while a process of **pebble$_2$** dispelling evil spirits is nomologically impossible, the process of my act of trying to dispel evil spirits with **pebble$_2$** is nomologically possible (e.g., carrying **pebble$_2$** in my pocket would be part of such a process).

Following Koslicki & Massin's argument, we assume that, at time t_3, **pebble$_2$** comes to bear the placebo capacity **d$_6$** to subjectively satisfy my desire to dispel evil spirits. To begin with, **d$_6$** is an extrinsic disposition, as **pebble$_2$** bears **d$_6$** in virtue of the existence of **intention$_3$**, external to **pebble$_2$**.

Subsequently, we consider whether the extrinsic disposition **d$_6$** is an intentional realizable entity. This requires both that (i) **d$_6$** comes into being through an intentional act and (ii) a realization of **d$_6$** is determined by an associated goal. First, **d$_6$** comes into being through my intentional act of mentally selecting **pebble$_2$** to dispel evil spirits. Second, one might consider the associated goal coming into being through **desire$_2$** as a process type whose achievement results in a process of **pebble**$_2$ dispelling evil spirits. However, this process type cannot exist as it is nomologically impossible.

Instead, we can consider the associated goal as a process type ($Goal_2$) whose achievement results in a process of my desire to dispel evil spirits being satisfied, because the association between intentional acts and goals can be indirect (see Section 3.2). Thus, $Goal_2$ determines a realization of **d$_6$**, namely a process of my desire to dispel evil spirits coming to be satisfied. Moreover, a successful act in which **intention$_3$** is realized is not a nomologically impossible process of **pebble$_2$** dispelling evil spirits, but a process of my desire to dispel evil spirits coming to be satisfied, which has as part a process of my desire to dispel evil spirits being satisfied, occurring with the achievement of $Goal_2$.

Finally, we consider whether the intentional realizable entity **d$_6$** is novel or not. In our view, there is no realizable entity *r* borne by **pebble$_2$** before time t_3 such that any realization of **d$_6$** (i.e., the process of my desire to dispel evil spirits coming to be satisfied) is also a realization of *r*. Therefore, **d$_6$** is a novel realizable entity. Consequently, **pebble$_2$** at time t_3 is a "product" (in the sense of the continuity view of production) according to our realizable-centered account of production and use (see Section 3.3).

We can therefore conclude that **pebble$_2$** at time t_3 is a material canonical artifact in virtue of bearing the novel intentional realizable entity **d$_6$**. Now, assume that the term "amulet" is defined as: "A material canonical artifact that bears a placebo capacity to subjectively satisfy a desire to dispel evil spirits." Given the continuity view of production, the canonical artifact **pebble$_2$** being produced in this way at time t_3 is explicable by **pebble$_2$** instantiating the class *Amulet* at time t_3—cf. Baker (2009, p. 84): "An amulet is a paradigm case of a technical artefact."

To generalize, we hypothesize that (material) faith-based artifacts may be characterized as a kind of (material) canonical artifacts because placebo capacities may be characterized as a kind of novel intentional realizable entities, particularly of novel intentional extrinsic dispositions. This hypothesis supports our analysis of canonical artifacts in terms of novel intentional realizable entities, encompassing novel intentional extrinsic dispositions (see Section 3.3).

4 Functions and Artifacts: A Realizable-Centered Perspective

In this section, we investigate the relationship between functions and artifacts from a realizable-centered perspective. Since the ontology of functions is by itself a foundational subject, our study of functions will be limited in scope.

First, we adopt an ontological and realism-based view of functions and leave aside, for example, Searle's (1995) "observer-relative" view of functions (and artifacts). Indeed, we are primarily interested in an ontological and largely realist theory of artifacts in this paper (see Section 2.1).

Second, we concentrate specifically on "artifactual functions" (such as the function of a screwdriver to turn screws) while leaving aside biological functions (such as the function of a lung to convey oxygen through the body). For clarity, we will occasionally use the term "function" to refer specifically to artifactual functions unless confusion arises.

Third, formal ontology contains a variety of accounts of functions (Carrara et al., 2011; Röhl & Jansen, 2014; Yargan & Jansen, 2024). Among these, we focus on three major theories: the designer-based theory, the etiological theory and the systemic theory—drawing inspiration from Koslicki & Massin's (in press) argumentation.

Fourth and relatedly, we provide realizable-based definitions for the corresponding terms "design function," "proper function," and "system function" (Section 4.1). We assume these functions form a subtype of realizable entities (cf. Roberts, 2024; Toyoshima & Jansen, 2026), while leaving aside the possibility that they can be a subtype of processes (see e.g., Burek, 2006). The view of function as a realizable entity helps us to sharply distinguish between "functions" (continuants) and "functionings" (occurrents) (Röhl & Jansen, 2014; Spear et al., 2016).

We examine the function-based accounts of artifacts by analyzing the relationship among these three kinds of functions (design, proper and system) and the kinds of realizable entities proposed in our realizable-centered approach to artifacts (Section 4.2).

4.1 Three Theories of Functions: Designer-Based, Etiological and Systemic

First, according to the designer-based theory, a function is determined by the intention(s) of the designer(s) of the function bearer (Baker, 2007). Here, "designer" is understood broadly to include authors, producers, inventors, and generally any agents responsible for creating the artifact or artifact kind. For instance, the function of a screwdriver to turn screws is determined by the designer's intention, as the designer intentionally produced (or designed) the screwdriver to perform this function. We provide the following realizable-based definition of the term "design function":

Definition 11 (design function)**.** *design function* $=_{\text{def.}}$ *A realizable entity (i) that comes into being through an intentional act of design and (ii) whose realization is determined by the designer's intention (or designers' intentions).*

We note that the phrase "is determined by" in this definition carries the same technical meaning as in Definition 1 (see Section 3.2 on intentional realizable entities).

Second, according to the etiological theory (aka causal-historical theory), a function of a bearer of a certain kind is determined by the successful production of an effect in past members of that kind, which explains why members of the kind continue to be selected or reproduced (Milikan, 1984, 1989; Neander, 1991; Wright, 1973). For instance, the function of this particular screwdriver (an instance of the type *Screwdriver*) to turn screws is determined by past successful instances of *Screwdriver* producing this effect, explaining why instances of *Screwdriver* continue to be used and reproduced. As a proper function is predicated upon a type of function bearer, we provide the following realizable-based definition of "proper function with respect to type *T*":

Definition 12 (proper function)**.** *proper function with respect to type* $T =_{\text{def.}}$ *A realizable entity of the bearer instantiating T whose realization is an effect (i) successfully produced by instances of T in the past and (ii) that explains why instances of T continue to exist.*

Third, according to the systemic theory (aka the causal contribution theory) of functions—which we formulate here using the notions of a capacity and its manifestation—a function is determined by the manifestation of a capacity of the bearer that causally contributes to the manifestation of a capacity by the system of which the bearer is a component (Borgo et al., 2016; Burek et al., 2016; Cummins, 1975; Mizoguchi et al., 2016). For example, the function of a screwdriver to turn screws can be analyzed in terms of the capacity of this screwdriver whose manifestation causally contributes to the manifestation of a capacity of the "screw-turning system," which has as component the screwdriver, a screw and an agent using the screwdriver.

The notion of a system function is based on the twin conceptual pillars: the notions of a system and causal contribution. Regarding systems, we assume that they can be intuitively understood as entities with two or more components related

in a specific way, although their ontological analysis remains challenging (Miettinen, 2018; Mizoguchi & Borgo, 2021; Perez, 2020; Rodrigues, 2023). For the related notion of a mechanism, see Machamer et al. (2000) and Röhl (2012).

The notion of a system connects to the ontology of realizable entities through Vetter's (2015, ch. 4.5) systemic account of extrinsic dispositions ("extrinsic potentialities" in her terms). The core idea is that bearing an extrinsic disposition is both necessary and sufficient for the bearing of a *joint disposition* ("joint potentiality" in her terms) by a system having as component the bearer and other objects. Here, a joint disposition (in the Vetter-inspired sense) is an intrinsic disposition, as outlined in Toyoshima et al.'s (2022c) formalization of this systemic account of extrinsic dispositions. System functions can be considered as a kind of extrinsic dispositions, as they exist within the system that includes the bearer.

Concerning causal contribution, we interpret it in terms of realizations of realizable entities, since intrinsic dispositions, and more generally realizable entities, can be seen as causal properties in philosophy (Mumford & Anjum, 2011; N. E. Williams, 2019b; Ingthorsson, 2021; cf. Nolan's (2015) dissenting voice) and in formal ontology (Röhl & Jansen, 2011; Toyoshima, 2020; Toyoshima et al., 2022c). By synthesizing these analyses of systems and causal contribution, we can provide the following realizable-definition of "system function":

Definition 13 (system function)**.** *system function* $=_{\text{def.}}$ *An extrinsic disposition whose realization causally contributes to a realization of an intrinsic disposition of a system of which the bearer is a component.*

4.2 Discussion: Beyond the Function-Based Accounts of Artifacts

For expository clarity, we examine the systemic, etiological and designer-based theories of functions in sequence, within the context of function-based accounts of artifacts. Our methodology involves scrutinizing, from our realizable-based perspective on material artifacts, how the notion of a material artifact is characterized in terms of bearing a [system/proper/design] function.

First, the systemic theory of functions struggles to account for many kinds of artifacts (as discussed in detail by Koslicki & Massin, in press). Consider, for example, material entities bearing novel intentional intrinsic dispositions: these are material canonical artifacts, yet they fall outside the scope of the systemic theory since any system function is an extrinsic disposition, and no intrinsic disposition can be a system function (see also Artiga, 2016; Röhl & Jansen, 2014).

It is worth noting that usefactual realized entities form a subtype of system functions—consider $\mathbf{d_2}$ borne by $\mathbf{pebble_2}$ at time t_2' (Example 5; see Section 3.5.1). In the ontology of functions, the term "use function" refers roughly to a function ascribed to an entity in virtue of an agent's actual usage for a purpose intended by the agent. More precisely, it aligns with Bahr's (2019) "sporadic user-intended function" or Toyoshima et al.'s (2022b) "narrow use function"; cf. Artiga's (2016) "functioning as" in contrast with "having a function." Examples include the use function of keeping papers in place of the naturefact $\mathbf{pebble_2}$ at time t_2'. From a realizable-based perspective, use functions can be considered as usefactual realized entities (Toyoshima et al., 2024b). Consequently, the system theory of functions is sometimes motivated to accommodate the notion of a use function (e.g., Mizoguchi et al., 2016).

Second, the etiological theory of functions encounters difficulties with "innovative or atypical artefacts" (Vermaas & Houkes, 2003, p. 266) or prototypes, defined as "a first exemplar of a newly created artifact kind" (Koslicki & Massin, in press). This difficulty arises because proper functions of instances of type T requires a causal history involving the successful production of an effect that explains the continued use and reproduction of T instances—something that prototypes lack by definition.

A related issue with the etiological theory is its relativity of proper functions to types of bearers, which makes types of bearers ontologically prior to types of proper functions. This makes the etiological theory less suitable for developing a general ontology of artifacts intended to remain neutral regarding definitions of domain-specific artifact-related terms such as "pot", "paperweight," "doorstop," and "amulet" (see Section 2.2; and Section 5.4 for a related issue concerning the BFO etiological account of functions).

Third, the designer-based theory of functions has limitations compared to our realizable-centered approach. Assuming that the notion of design primarily characterizes canonical artifacts, we now compare design functions with novel intentional realizable entities, or more generally with intentional realizable entities. First of all, design functions come into being through an intentional act of design (item (i) of Definition 11), whereas intentional realizable entities come into being through an intentional act *simpliciter* (item (i) of Definition 1). Clarifying their comparison requires disambiguating the term "design."

There are at least two interpretations of "design": a broad one, where an intentional act of design need not involve physical modification and may include mental selection, and a narrow one, where an intentional act of design must involve physical modification and excludes mere mental selection.

This ambiguity creates a dilemma. If one accepts the broad interpretation, defining "material artifact" as "a material entity that bears a design function" may fail to sharply distinguish canonical artifacts (e.g., **clay$_1$** at time t_1 in Example 1) from usefacts (e.g., **pebble$_2$** at time t_2 in Example 2). If one accepts the narrow interpretation, the same definition may exclude canonical artifacts involving appropriation, such as ready-made artworks (see Sections 3.2 and 3.3). Either way, the notion of design struggles to underpin a plausible conception of canonical artifacts.

Moreover, realizations of design functions are determined by the designer's intention (or designers' intentions) (item (ii) of Definition 11), whereas realizations of intentional realizable entities are determined by an associated goal (item (ii) of Definition 1). To clarify the difference, consider (material) faith-based artifacts, which we analyzed as a kind of (material) canonical artifacts (see Section 3.5.2). The designer-based theory could characterize **pebble$_2$** at time t_3 in Example 6 as a material artifact bearing the design function of dispelling evil spirits. However, this analysis commits to the controversial claim that some realizable entities have realizations that are nomologically impossible (though see Jenkins & Nolan, 2012). In contrast, our analysis of Example 6 in terms of placebo capacities avoids this problematic view of realizable entities and functions—cf. Preston's (2013, p. 177) "phantom function" as a function that a kind of artifact is "constitutionally incapable of performing"; see also Holm's (2017) critical examination.

Finally, a "pluralist" function-based account of artifacts combining two or more theories of functions would face similar issues (Koslicki & Massin, in press). For instance, one might attempt to characterize canonical artifacts and usefacts using design functions and use functions, respectively, on the assumption that both are reducible to systemic functions, and consequently, no design functions are intrinsic dispositions (cf. Mizoguchi et al., 2016). This systemic and designer-based theory (enriched with use function) would nonetheless inherit the challenges of each individual theory. To illustrate with Example 6, it remains unclear whether the agent at time t_3 is a "designer" or "user" with respect to **pebble$_2$**, making it uncertain whether **pebble$_2$** at time t_3 is a canonical artifact or a usefact, unless "designer intentions" and "user intentions" are clearly specified. This uncertainty stems from the limitations of the intention-based approach to artifacts, particularly with respect to the designer-based theory of functions.

In sum, we examined traditional, function-based accounts of artifacts from a realizable-centered perspective, by considering three prominent theories of functions (viz., designer-based, etiological and systemic) or more concretely, by scrutinizing realizable-based characterizations of "design function," "proper function," and "system function." This leads us to conclude that, despite their intuitive appeal (especially for design functions), these function-based accounts of artifacts (whether monist or pluralist) lack the generality of the realizable-centered approach to artifacts we develop here.

5 Formalizing a Realizable-Centered Approach to Artifacts: A Case Study Using Basic Formal Ontology

We demonstrate the flexibility and applicability of our realizable-centered approach to artifacts by adapting it to BFO, an established upper ontology. After preliminaries (Section 5.1), we introduce the terms "artifactual capacity" and "independent continuant artifact," which align terminologically and conceptually with the BFO framework (Section 5.2). We then formally characterize these terms (Section 5.3) and conclude with a brief discussion (Section 5.4).

We choose BFO for this case study for several reasons. First, BFO serves as a useful illustrative example, as our theory of artifacts can be easily adapted to BFO among upper ontologies. Second, this case study contributes to developing a BFO-compliant ontology of artifacts, a project that has been largely unexplored to date (see Section 5.1.2). Third, it clarifies the BFO category of realizable entity, particularly functions and roles within it (see Section 5.4).

5.1 Preliminaries

5.1.1 A General Overview of BFO. Figure 2 provides a taxonomy of classes, including terms from BFO and our new terms to be introduced in Section 5.2. This taxonomy maps BFO class terms to class terms (in square brackets) from the taxonomy introduced in Section 2.1 (see Figure 1). Strictly speaking, BFO does not include the category of externally grounded realizable entity (parenthesized here), as the term "externally grounded realizable entity" is used to explain the BFO category of role; however, we include it to show the correspondence between this BFO term and our term "extrinsic disposition" (Toyoshima et al., 2022c).

BFO includes the top-level distinction between continuants and occurrents. On the continuant side, independent continuants include material entities such as organisms and heaps of stones. They also include immaterial entities, with sites as one subtype. A BFO:site is defined as: "An immaterial entity in which objects such as molecules of air or organisms can be contained" (Arp et al., 2015, p. 184; see also Donnelly, 2005). Examples include my nasal cavity and the hold of a ship.

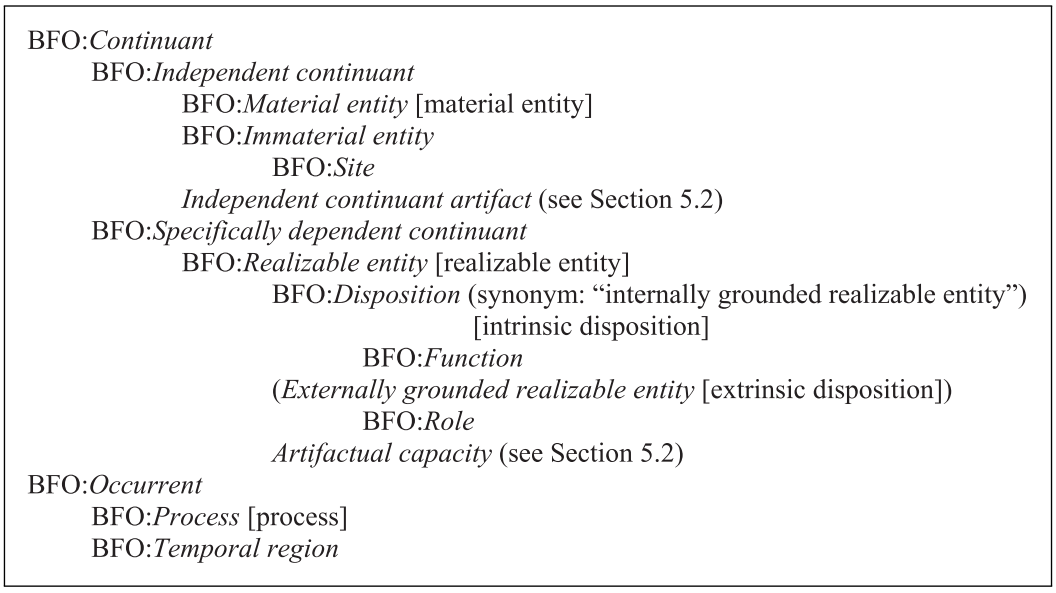

Figure 2. A BFO-based taxonomy of classes used in Section 5.

A specifically dependent continuant is a continuant that depends (existentially) on at least one independent continuant. A realizable entity is a specifically dependent continuant that can be realized in associated processes of specific correlated types in which the bearer participates. BFO currently includes three subtypes of realizable entities: dispositions, functions, and roles.

A disposition in BFO is a realizable entity that exists because of certain features of the physical makeup of its bearer—the independent continuant that bears it. It is an "internally grounded realizable entity": if a BFO:disposition ceases to exist, then the physical makeup of the bearer is changed. Examples include the fragility of a glass and the flammability of a match.

A function in BFO is a BFO:disposition of a bearer with a specific kind of historical development. It is a BFO:disposition that its bearer possesses in virtue of its having a certain physical makeup because of how it came into being, either through evolution (for natural biological entities) or intentional design (for artifacts). Spear et al. (2016, p. 126) explain: " 'Came into being' here strongly suggests that a functional disposition is one whose existence helps to causally explain the existence of the entity, or at least of the physical structure, that it is a disposition of." Examples include the function of the heart to pump blood through the body or the function of a screwdriver to turn screws.

A role in BFO is a realizable entity that (1) exists because the bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be (optionality), and (2) is not such that, if this realizable entity ceases to exist, then the physical makeup of the bearer is changed (external grounding). Briefly, a BFO:role is an externally grounded and optional realizable entity. Examples include the role of being a student and the role of a stone marking a boundary. For further discussion on optionality here, see Röhl & Jansen, 2014; Toyoshima et al., 2022c; see also Toyoshima's (2021) foundational analysis of roles in BFO.

On the occurrent side, a process is an occurrent that exists in time by occurring—that is, by having temporal parts—and depends on at least one independent continuant as a participant. Examples of processes include cell division or a person's walk. A temporal region is an occurrent that is part of (the whole of) time.

5.1.2 Existing BFO-Compliant Definitions of the Terms "Artifact" and "Material Artifact". Several BFO-compliant definitions of "artifact" and "material artifact" exist in the literature:

(d1) artifact $=_{\text{def.}}$ A material entity created or modified or selected by some agent to realize a certain [BFO:]function or [BFO:]role. (Ceusters & Smith, 2015, p. 1)
(d2) artifact $=_{\text{def.}}$ Something that is deliberately designed (or, in certain borderline cases, selected) by human beings to address a particular purpose. (Arp et al., 2015, p. 3)
(d3) artifact $=_{\text{def.}}$ A material entity that has been intentionally selected by some agent to serve in attaining some end and is recognized in some community as having been created for some purpose. (Duncan, 2017, p. 26)

(d4) artifact $=_{\text{def.}}$ An object designed by an agent to fulfill a certain [BFO:]function (Otte et al., 2019, p. 181)
(d5) material artifact $=_{\text{def.}}$ An object deliberately created to have a certain [BFO:]function. (Drobnjakovic et al., 2022, p. 7)
(d6) material artifact $=_{\text{def.}}$ A material entity that was designed by some agent to realize a certain [BFO:]function. (The Common Core Ontologies Repository, 2024; see also Jensen et al., 2024)

These six definitions suggest that "artifact" should refer to canonical artifacts (entities intentionally produced for a specific purpose) within the BFO framework. First, the term "created" may imply a non-continuity view of production (d1, d3, d5). Second, terms like "intentionally" and "deliberately" are used (d2, d3, d5). Third, the term "purpose" (d2, d3) and the expression "to realize/have/fulfill a certain [BFO]:function" (d1, d4, d5, d6) are used. Fourth, the term "[BFO]:function" is explicitly referenced (d1, d4, d5, d6) and, by definition (or elucidation), BFO:functions come into being through *intentional* design.

5.2 Defining the Terms "Artifactual Capacity" and "Independent Continuant Artifact"

Based on the discussion in Section 5.1.2, we adapt the notions of a canonical artifact and a novel intentional realizable entity to the BFO ontological framework. Recognizing the importance of "terminological choice" (and ontological analysis) in ontology development (Neuhaus & Hastings, 2022), we introduce more accessible terms instead of using our technical terms "material canonical artifact" and "novel intentional realizable entity."

For an alternative to "material canonical artifact," we propose "independent continuant artifact." First, we retain the term "artifact," as existing BFO-compliant definitions of the term "(material) artifact" imply that it should refer to canonical artifacts (see Section 5.1.2). Second, we introduce "independent continuant artifact" instead of "material artifact" because some canonical artifacts are arguably independent continuants that are not material entities. For instance, trenches created during the First World War may be classified as BFO:sites. Given that BFO:sites can bear specifically dependent continuants (though see Neuhaus, 2026), they qualify as canonical artifacts by bearing novel intentional realizable entities.

For an alternative to "novel intentional realizable entity," we propose "artifactual capacity." We use here the term "capacity" for several reasons. First, capacity-based approaches to artifacts have been developed in formal ontology and in philosophy (Borgo & Vieu, 2009; Kassel, 2010; Koslicki & Massin, 2025; see also Section 7).

Second, while "capability" and "capacity" are sometimes considered as synonymous, a BFO-based analysis treats capabilities are a subtype of BFO:dispositions (Beverley et al., 2024). In contrast, we argue that canonical artifacts should be characterized by novel intentional realizable entities, rather than novel intentional intrinsic dispositions, where our term "intrinsic disposition" aligns with BFO:*Disposition* (see Section 2.1).

Third, the notion of a capacity can accommodate both intrinsic and extrinsic dispositions, including novel intentional extrinsic dispositions. For instance, Koslicki and Massin's (2025) "placebo *capacities*" can be analyzed as novel intentional extrinsic dispositions (see Section 3.5.2). Capacities are also characterized as "relational qualities," synonymous with our term "extrinsic property," according to a DOLCE-compliant analysis of functions, capabilities and capacities in the engineering domain (Borgo et al., 2021; Compagno, 2025; Compagno & Borgo, 2024b; Compagno et al., 2023).

We define "artifactual capacity" and "independent continuant artifact" as follows, acknowledging the needs for a BFO-friendly reinterpretation of the term "goal" in the definition of the former term:

artifactual capacity $=_{\text{def.}}$ A realizable entity *r* (1) that comes into being through an intentional act; (2) whose realization is determined by an associated goal; and (3) such that the bearer has no realizable entity *r'* such that (i) *r'* exists before *r* comes into being and (ii) if *r* is realized in a process, then *r'* is realized in the same process.

independent continuant artifact $=_{\text{def.}}$ An independent continuant that bears an artifactual capacity.

We make some clarificatory remarks on the definition of "artifactual capacity." First, it is clear that items (1) and (2) correspond to the notion of an intentional realizable entity, while item (3) corresponds to the notion of a novel realizable entity. Relatedly, the definition of "independent continuant artifact" is not circular despite involving "*artifactual* capacity," just as "material usefact" can be non-circularly defined using "*usefactual* realizable entity" (see Section 3.4, especially Definitions 7 and 6').

Second, we may need to reinterpret the term "goal" in a BFO-conformant way, as viewing goals as process types coming into being through some occurrent desire could conflict with BFO's realist methodology (see Section 2.3). The notion of a goal remains understudied in BFO-based ontology research. The BFO-compliant Information Artifact Ontology (IAO; Ceusters & Smith, 2015) defines "object specification" as "a directive information entity that describes an intended process

Table 1. Predicates and Their Informal Explanation.

Predicate	Their Informal Explanation
AC(x)	x is an artifactual capacity. [introduced by us]
ICA(x)	x is an independent continuant artifact. [introduced by us]
INC(x)	x is an independent continuant.
RE(x)	x is a realizable entity.
EXT(x,y)	x (entity) exists at t (temporal region)
PREC(x,y)	x (occurrent) precedes y (occurrent) (cf. Arp et al., 2015, pp. 141–142)
INH(x,y)	x (specifically dependent continuant) inheres in y (independent continuant)
REA(x,y)	x (realizable entity) realizes y (process)

endpoint" and lists "goal specification" as a synonym (http://purl.obolibrary.org/obo/IAO_0000005); for more details, see Duncan et al.'s (2024) analysis of the related IAO term "plan specification." Based on this, we may loosely characterize a goal as a realizable entity that comes into being through some occurrent desire, such that it can be realized in "an intended process endpoint," though this raises questions about which entity or entities bear the goal. We leave for future work a BFO-based rigorous characterization of goals.

5.3 Formal Characterization

We formalize "artifactual capacity" and "independent continuant artifact" in classical first-order logic, as this formalization aligns with existing ontologies (notably BFO) and avoids potential conceptual and technical issues with modal logical representations of realizable entities (including dispositions) in BFO (Toyoshima & Niki, 2021). Our first-order language includes a countably infinite supply of variables (for particulars only), standard logical symbols (including "¬," "∧," "," "∀," and "∃") and predicates from Table 1 (imported from BFO unless specified otherwise). Free variables are universally quantified when ambiguity is absent and parentheses are used conventionally.

First of all, an artifactual capacity is a realizable entity:

$$\mathbf{A}1 \quad \mathrm{AC}(x) \rightarrow \mathrm{RE}(x)$$

For items (1) and (2) in the definition of the term "artifactual capacity," formal representation is challenging due to the complexity of notions such as intentional act, determination ("is determined by") and goal (see Section 5.2). However, one possible way to formalize item (1) is to introduce the primitive predicate IA(x) ("x is an intentional act"), adopt the "results in formation of" relation (http://purl.obolibrary.org/obo/RO_0002297) from the BFO-compliant relation ontology (RO; Smith et al., 2005), reinterpret it more broadly as a relation (RF(x,y)) between a process and a continuant (not restricted to an anatomical entity) and state the following axiom: $\mathrm{AC}(x) \rightarrow \exists y(\mathrm{IA}(y) \wedge \mathrm{RF}(y,x))$.[8] Informally, this reads as: "any artifactual capacity is formed as a result of some intentional act."

For item (3) in the definition, we formalize it using existing BFO relations:

$$\begin{aligned}\mathbf{A}2 \quad \mathrm{AC}(x) \rightarrow \exists y, t_x[&\mathrm{INH}(x, y) \wedge \mathrm{EXT}(x, t_x) \wedge \neg\exists r, t_r[(\mathrm{RE}(r) \wedge \mathrm{INH}(r, y) \wedge \\ &\mathrm{EXT}(r, t_r) \wedge \mathrm{PREC}(t_r, t_x) \wedge \forall p(\mathrm{REA}(x, p) \rightarrow \mathrm{REA}(r, p))]]\end{aligned}$$

(A2) can be informally read as: "Any artifactual capacity *x* inheres in an independent continuant *y* such that there is no other realizable entity *r* in *y* that exists before *x* comes into being and such that any of realizations of *x* is a realization of *r*."

We formally define "independent continuant artifact" as follows:

$$\mathbf{D}1 \quad \mathrm{ICA}(x) \triangleq \mathrm{INC}(x) \wedge \exists y(\mathrm{AC}(y) \wedge \mathrm{INH}(y,\ x))$$

(D1) can be informally read as: "An independent continuant artifact *x* is, by definition, an independent continuant in which some artifactual capacity inheres."

5.4 Discussion: Clarifying Functions and Roles in BFO

We saw in Section 5.1.2 that existing BFO-compliant definitions of the terms "artifact" and "material artifact" tend to rely on the BFO category of realizable entity, particularly function. In that respect, our realizable-centered approach to artifacts can clarify realizable entities in BFO.

Initially, let us compare artifactual capacity with BFO:function. There are several key ontological differences between them. First, BFO:functions are a subtype of BFO:dispositions (or internally grounded realizable entities), whereas artifactual capacities can be externally grounded realizable entities. A case in point is Koslicki and Massin's (2025) "placebo capacities" (e.g., $\mathbf{d_6}$ borne by $\mathbf{pebble_2}$ at time t_3 in Example 6). Placebo capacities are artifactual capacities but are BFO:roles. In particular, they are optional realizable entities, as $\mathbf{d_6}$ exists because $\mathbf{pebble_2}$ is in contingent circumstances in which it does not have to be, to wit, the existence of $\mathbf{intention_3}$.

Second, BFO's theory of functions seems to be committed to the non-continuity view of production, as the BFO notion of a function is closely tied to how the bearer "came into being" and helps to causally explain the bearer's existence. As the BFO theory of functions also seems to assume the continuity view of use, it may embody a typical hybrid approach to production and use (see Section 2.2). In contrast, the notion of an artifactual capacity is intended to be neutral with respect to whether the hybrid or monolithic approach is adopted; see Section 7.1 for discussion on adapting our approach to the non-continuity view, especially the constitution view, of both production and use.

Third, artifactual BFO:function is etiological and designer-based, as BFO explicitly endorses an etiological account of functions (Spear et al., 2016) and, for artifacts (to wit, canonical artifacts), intentional design is causally responsible for the physical makeup of the bearer of a BFO:function. We note, however, that while BFO claims functions to be etiological, artifactual BFO:functions would not qualify as proper functions in the sense of Definition 12 (see Section 4.1), as the intentional design involved in a given BFO:function pertains to the causal history *of the particular bearer*: "In the case of artifacts, the current [BFO:]function of an artifact is determined by *its* history of intentional design or selection by some agent" (Spear et al., 2016, p. 109, our italics added).

As a result, the BFO account of artifactual functions may inherit the issues of the etiological and designer-based theories of functions in providing a general ontology of artifacts (see Section 4.2). For instance, we raised concerns about types of bearers of proper functions being ontologically prior to types of these proper functions. Similar concerns might be formulated in BFO: "For BFO, [. . .] if a function of a given kind exists, then its bearer must instantiate some independent continuant biological or artifactual universal. [. . .] we take reference to kinds to be unavoidable in almost all talk of functions and take the question of whether or not a given thing has a function to be, at least in part, a question of the kind of thing it is" (Spear et al., 2016, p. 123).

Another issue is the ambiguity of the term "design" (e.g., whether it should be broadly construed to include mental selection or narrowly to require physical modification), as noted when we examined the designer-based theory of functions. This ambiguity is evident in BFO's explanations of functions, which sometimes refer to "selection" alongside intentional design: "this bearer [of a BFO:function] came into existence as a result of [. . .] intentional design *or selection* for artifacts" (Spear et al., 2016, p. 107, our italics added) and "In the case of artifacts, the current [BFO:]function of an artifact is determined by its history of intentional design *or selection* by some agent" (Spear et al., 2016, p. 109, our italics added).

Following this, we compare BFO:role with artifactual capacity and usefactual realizable entity (see Section 3.4, especially Definition 7). First, we have already argued that some artifactual capacities (e.g., placebo capacities such as $\mathbf{d_6}$) are BFO:roles and they fall outside the scope of BFO:function.

Second, usefactual realizable entities are BFO:roles, as illustrated by $\mathbf{d_2}$ (borne by $\mathbf{pebble_2}$ at time t_2 in Example 2) and $\mathbf{d_3}$ (borne by $\mathbf{clay_1}$ at time t_1' in Example 3). Specifically, they are optional realizable entities, as $\mathbf{d_2}$ exists because $\mathbf{pebble_2}$ is in contingent circumstances in which it does not have to be, to wit, the existence of $\mathbf{intention_2}$.

Furthermore, previous BFO-based analyses of functions have noted the existence of BFO:roles closely related to but distinct from BFO:functions. For instance, Spear et al. (2016) state: "when sticks from the woods are *merely intentionally selected* to be used as chopsticks, then they do not take on or have a function at all in the BFO sense, but rather a [BFO:]*role*" (Spear et al., 2016, p. 126) and "naturefacts and [. . .] (merely intentionally) repurposed artifacts generally [. . .] do not have functions in the BFO sense; but rather [BFO:]roles" (Spear et al., 2016, p. 127). As another example, Röhl and Jansen (2014, p. 14) argue: "the so-called 'use functions' [. . .] are to be classified as roles [. . .] in agreement with the BFO conception of roles."

When BFO:roles come into being when their bearers (e.g., wooden sticks) "are merely intentionally selected to be used" for some accidental purpose (e.g., to serve as chopsticks), these BFO:roles can be analyzed as usefactual realizable entities. We can further add that naturefacts can be defined in terms of usefactual realized entities—a subtype of usefactual realizable entities (see Section 3.5.1)—and that, in Example 3, $\mathbf{clay_1}$ at time t_1' is a "(merely intentionally) repurposed

artifact" and the usefactual realizable entity $\mathbf{d_3}$ (borne by $\mathbf{clay_1}$ at time t_1') is a BFO:role. Recall also that use functions can be considered as usefactual realized entities (see Section 4.2).

In sum, our realizable-centered approach to artifacts clarifies functions and roles in BFO. On the one hand, artifactual BFO:functions can be understood as a specific kind of artifactual capacities. On the other hand, some BFO:roles are artifactual capacities while others are usefactual realizable entities. Although such use-related BFO:roles have been previously mentioned in the literature, we analyzed them systematically from a realizable-centered perspective on usefacts.

6 Discussion

6.1 The Individuation of Realizable Entities

Since our realizable-centered approach to artifacts hinges on the ontology of realizable entities, the individuation and categorization of these entities are crucial—that is, determining which realizable entities exist and how a realizable entity is to be characterized. These determine which entities (particularly material entities) qualify as canonical artifacts, usefacts, or neither—and whether an entity can qualify as both.

To illustrate, suppose that at time t_4, $\mathbf{pebble_2}$ is intentionally shaped into a cube (recall Example 2). On the one hand, $\mathbf{pebble_2}$ at time t_4 would be a canonical artifact if the intrinsic disposition $\mathbf{d_2}$' of $\mathbf{pebble_2}$ to keep papers in place ceases to exist due to intentional shaping, and a novel intentional intrinsic disposition $\mathbf{d_2}$* of $\mathbf{pebble_2}$ (say, to keep papers in place tightly) comes into being at time t_4. On the other hand, $\mathbf{pebble_2}$ at time t_4 would be a usefact if $\mathbf{d_2}$ "survives" the intentional shaping and continues to exist after time t_4 and $\mathbf{d_2}$* is non-novel because of $\mathbf{d_2}$'. Generally, the individuation of realizable entities (as exemplified by the issue of the existence of $\mathbf{d_2}$' at time t_4) is open to a variety of interpretations, sometimes leading to indeterminacy between classifying an entity as a canonical artifact or as a usefact.

Several approaches can tackle the thorny issue of individuating realizable entities. One pragmatic view holds that their individuation primarily requires domain-specific knowledge, with different domain ontologies adopting distinct principles established through "consensus creation" (Neuhaus & Hastings, 2022) among ontology developers and domain experts. For example, Arp et al. (2015, p. 102) acknowledge "the problem as to how [BFO:]dispositions are to be individuated" and state: "BFO itself does not provide a taxonomy of dispositions; it does not itself legislate concerning which types of dispositions exist, or how they are to be individuated. Rather, it leaves this task to the specific sciences" (Arp et al., 2015).

However, a domain-neutral principle for individuating realizable entities would be desirable. To explore this, consider Barton et al.'s (2018c) work on the (synchronic) identity of intrinsic dispositions. As a preliminary, we introduce the notions of a *trigger* and a *categorical basis* of an intrinsic disposition. A trigger of an intrinsic disposition is a process whose occurrence activates the realization of the intrinsic disposition; cf. McKitrick's (2018, ch. 6) event-based view of triggers within her dispositional pluralism. A categorical basis of an intrinsic disposition is a categorical (i.e., non-realizable) property (e.g., physical structure) of the bearer in virtue of which the intrinsic disposition exists (Prior et al., 1982; Röhl & Jansen, 2011). For example, the fragility of this glass is an intrinsic disposition that can be triggered by a process of pressing the glass with sufficient force and whose categorical basis is a specific molecular structure of the glass.

According to one criterion for the identity of intrinsic dispositions ("parthood criterion" in Barton et al.'s (2018c) terms), two intrinsic dispositions are identical if and only if they have the same categorical basis, the same class of minimal triggers and the same class of maximal realizations. The class of minimal triggers of a disposition d is the class of triggers of d for which no proper part is a trigger of d. The class of maximal realizations of d is the class of realizations of d which are not proper parts of another realization of d. To put it epistemically, according to this criterion, the identification of an intrinsic disposition amounts to the identification of the associated categorical property (or properties), the "smallest causal factor" which exceeds the threshold value for causation and the resulting whole causal chain of processes. Barton et al. argue that this criterion avoids "disposition multiplicativism": the arbitrary proliferation of intrinsic dispositions that could undermine their causal and explanatory roles.

It would be valuable to extend the parthood criterion for the identity of intrinsic dispositions to the entire category of realizable entities, thereby developing a domain-neutral principle for individuating realizable entities. On the one hand, the notion of a categorical basis of an intrinsic disposition can be generalized to the broader notion of a categorical basis of a realizable entity (cf. Ferreira Ruiz & Hundertmark, 2024), as Toyoshima et al. (2022c) elaborate this notion with a focus on the causal import of realizable entities.

On the other hand, extending the notion of a trigger of an intrinsic disposition to the more general notion of a trigger of a realizable entity is more intricate. This difficulty arises partly because even the former notion remains largely unexplored in formal ontology and in philosophy. In biomedical ontologies, for instance, Röhl and Jansen (2011, p. 5) note: "It is true that in many cases the trigger of [an intrinsic] disposition might not be known, and in other cases we may even have good

reasons to assume that no trigger is involved." The latter claim aligns with McKitrick's (2018, ch. 6) philosophical argument for "trigger-less dispositions" (e.g., the intrinsic disposition of uranium to decay) within her dispositional pluralism. This presents a theoretical challenge to attempts to define a trigger notion characterizing all realizable entities. Moreover, Röhl and Jansen's former claim raises practical concerns about the applicability of a trigger-based characterization (if any) of realizable entities to ontology development. These theoretical and practical issues regarding triggers of realizable entities—encompassing both intrinsic and extrinsic dispositions—remain as key pointers for addressing the problem of individuation of realizable entities.

6.2 The Identity of Processes

Besides the individuation of realizable entities, the identity of processes is also a foundational topic relevant to our realizable-centered approach to artifacts, as Definition 2 (of "novel realizable entity") relies on process identity—item (ii) being: "if *r* is realized in a process, then *r'* is realized in the *same process.*" The same remark applies to the definition (i.e., Definition 5) of the relation "is non-novel because of" as well. The identity of processes significantly influences whether a realizable entity is novel or not, and consequently, which (material) entity is a canonical artifact or a usefact.

While the general notion of an identity criterion goes beyond the scope of this paper (Garbacz, 2022, 2023), we present two major views of processes in formal ontology: the *manifestation view* and the *quality-change view*; for details, see Rodrigues's (2023) discussion on these views. We briefly consider two corresponding identity criteria for processes (cf. Toyoshima & Barton, 2024b) with respect to our goal of elucidating the notion of a novel realizable entity.

First, the manifestation view is typically summarized as "events are manifestation of dispositions." Paraphrasing in our terms, processes are realizations of realizable entities, particularly intrinsic dispositions. For instance, a process of this glass breaking can be analyzed as a realization of the fragility of the glass. This view underpins the UFO class *Perdurant* and has been practically applied in ontology-driven conceptual modeling (Almeida et al., 2019; Guizzardi et al., 2013; Guzzardi et al., 2016).

According to a simple version of the manifestation-based criterion for process identity, two processes are identical if and only if they realize the same intrinsic disposition(s) at the same time (Toyoshima & Barton, 2024b). As intrinsic dispositions are causal properties (see Section 4.1), this criterion may be seen as a (partial) dispositional interpretation of a causal criterion for the identity of processes: processes are identical if and only if they have the same causes and effects (Davidson, 1969).

Second, the quality-change view has been developed by Guarino et al. (2022), who use the term "event" rather than "process." Central to their theory of events is the notion of a *qualitative change*, individuated by the triple $<o, q, t>$ where o is an object (roughly, a material entity in our terms), q is an "(individual) quality" (as in DOLCE and UFO; see Section 7.1) and t is a time interval during which q exists. They also describe o as a "changing object" or the "object of change" (e.g., this flower) and q as a "changing quality" or the "subject of change" (e.g., the color of this flower), respectively.

Moreover, a qualitative change $<o, q, t>$ is a *direct qualitative change* if q inheres in o and it is an *indirect qualitative change* if q inheres in one proper part of o. Then: "Direct and indirect qualitative changes are collectively called *simple events*" (Guarino et al., 2022, p. 261). To borrow their illustrative example, when a man gesticulates by moving his hand, we can identify at least two simple events: the direct qualitative change < the hand, the hand position, t'> ("hand-moving change") and the indirect qualitative change < the man, the hand position, t'> ("gesticulation change"). A straightforward criterion for the identity of simple events is that two simple events $<o_1, q_1, t_1>$ and $<o_2, q_2, t_2>$ are identical if and only if (i) o_1 is identical with o_2, (ii) q_1 is identical with q_2, and (iii) t_1 is identical with t_2.

In our view, both the manifestation view and the quality-change view of processes offer potential criteria for the identity of processes in general. Further investigation is needed to adapt these views to elucidate the notion of a novel realizable entity. For instance, the development of the manifestation view will necessitate a robust ontological account of the identity of realizable entities (see Section 6.1). Both views of processes will need closer examination to be adapted to upper ontologies such as BFO, DOLCE and UFO; for related studies of processes in BFO, see Toyoshima and Barton (2024b) and Ceusters and Ruttenberg (2025).

6.3 Use for Production

As mentioned in Section 3.1, our realizable-centered approach to artifacts postulates the narrow interpretation of the term "use" (where use is distinct from production) in contrast to the broad interpretation (where production is a kind of use). To explore the idea underlying the broad interpretation, we investigate a kind of use (within the narrow interpretation) intimately linked with production, under the name of "use for production." Let us introduce the following example:

Example 7 (use for production)**.** *At time t_0 (before time t_1), **clay**$_1$ is intended to be used to be able to contain liquid.*

Informally, we can think of $\mathbf{clay_1}$ at time t_0 as a usefact because it is intended to be used for the accidental purpose of being able to contain liquid, or more simply, because it is a natural object that is intended to be used for some purpose. We focus on $\mathbf{intention_0}$, the intention to use $\mathbf{clay_1}$ to be able to contain liquid and the extrinsic disposition $\mathbf{d_0}$ of $\mathbf{clay_1}$ to be able to contain liquid that comes into being at time t_0. And $\mathbf{d_0}$ is an extrinsic disposition, as $\mathbf{clay_1}$ bears $\mathbf{d_0}$ in virtue of the existence of $\mathbf{intention_0}$, external to $\mathbf{clay_1}$.

Recall now Example 1: at time t_1, $\mathbf{clay_1}$ is intentionally shaped and dried to be able to contain liquid. We analyzed this as $\mathbf{clay_1}$ at time t_1 being a canonical artifact in virtue of bearing the novel intentional realizable entity $\mathbf{d_1}$, with $\mathbf{d_1}$ coming into being through $\mathbf{act_1}$—the successful act of intentionally shaping and drying $\mathbf{clay_1}$. Given the continuity between Examples 7 and 1, $\mathbf{d_0}$ is realized in $\mathbf{act_1}$, even if it could have been, in principle, realized in alternative processes in which $\mathbf{clay_1}$ comes to be able to contain liquid—such as casting it in a mold—rather than a process (e.g., $\mathbf{act_1}$) of intentionally shaping and drying $\mathbf{clay_1}$. Since $\mathbf{act_1}$ is a production process (through which $\mathbf{d_1}$ comes into being), we can regard $\mathbf{d_0}$ as a realizable entity embodying the notion of "use for production": $\mathbf{clay_1}$ at time t_0 would be a usefact in virtue of bearing $\mathbf{d_0}$, and $\mathbf{d_0}$ is realized in a process (namely $\mathbf{act_1}$) in which $\mathbf{clay_1}$ becomes a canonical artifact at time t_1.

To justify the idea of use for production, we must show that $\mathbf{clay_1}$ at time t_0 is a usefact in virtue of bearing $\mathbf{d_0}$: specifically, in virtue of which realizable entity is $\mathbf{d_0}$ non-novel? To address it, we introduce the notion of "pre-realizable entity": a realizable entity that can be realized in a process in which another realizable entity of the bearer comes into being. In formal ontology, the notion of a "predisposition"—defined as "a disposition to acquire a (further) disposition"—has been developed and applied in the biomedical domain (Barton et al., 2018b; Scheuermann et al., 2009). From our perspective, a predisposition can be analyzed as an intrinsic disposition that can be realized in a process in which another intrinsic disposition of the bearer comes into being, as the term "disposition" traditionally refers to an intrinsic disposition. For that matter, Vetter (2015) elaborates the philosophical notion of an "iterated potentiality," which is more general than the notions of a predisposition and a pre-realizable entity.

Drawing on the notion of a pre-realizable entity, we can analyze the extrinsic disposition $\mathbf{d_0}$ of $\mathbf{clay_1}$ to be able to contain liquid as an extrinsic disposition to acquire an intrinsic disposition of $\mathbf{clay_1}$ to contain liquid. We now turn to the *intrinsic* disposition $\mathbf{d_0}$' of $\mathbf{clay_1}$ to be able to contain liquid, which exists before time t_0. We can analyze $\mathbf{d_0}$' similarly in terms of the notion of a pre-realizable entity, or particularly of a predisposition: $\mathbf{d_0}$' is an intrinsic disposition to acquire an intrinsic disposition to contain liquid. From this interpretation of $\mathbf{d_0}$ and $\mathbf{d_0}$', it follows that $\mathbf{d_0}$' exists before $\mathbf{d_0}$ comes into being and, if $\mathbf{d_0}$ is realized in a process of $\mathbf{clay_1}$ coming to bear an intrinsic disposition to contain liquid, then $\mathbf{d_0}$**'** is realized in the same process. Therefore, $\mathbf{d_0}$ is non-novel because of $\mathbf{d_0}$'. As a matter of fact, both $\mathbf{d_0}$ and $\mathbf{d_0}$**'** are realized in $\mathbf{act_1}$ and, through this process, $\mathbf{clay_1}$ comes to bear the intrinsic disposition $\mathbf{d_1}$ to contain liquid.

Our notion of use for production rests on the hypothesis that there are pre-realizable entities such as the intrinsic disposition $\mathbf{d_0}$' of $\mathbf{clay_1}$ at time t_0 to acquire an intrinsic disposition to contain liquid. Confirming this hypothesis is challenging due to its close ties to the complex issue of individuating realizable entities (see Section 6.1). However, for instance, there is a general agreement in the biomedical domain that an organism with a moderate genetic factor may possess an intrinsic disposition—a predisposition—to acquire a disease, where "disease" itself is treated as an intrinsic disposition in the BFO-compliant Ontology for General Medical Science (OGMS; Scheuermann et al., 2009). By analogy, we can argue that, due to its specific physical structure, $\mathbf{clay_1}$ at time t_0 bears the intrinsic disposition $\mathbf{d_0}$' (which is a predisposition) to acquire an intrinsic disposition to contain liquid.

7 Related Work

We review preceding works on artifacts, focusing first on Borgo and Vieu's (2009) theory of artifacts in formal ontology (Section 7.1). Indeed, our approach is substantially inspired by their theory, and their commonalities and differences will be valuable to analyze. Moreover, as already announced, we will consider how our approach can be reformulated within their constitution view of both production and use, demonstrating its adaptability to both monolithic and hybrid approaches to production and use. We later discuss additional theories of artifacts (Section 7.2) in philosophy (with a focus on the continuum problem between natural objects and artifacts; Section 7.2.1) and in formal ontology (Section 7.2.2).

7.1 Borgo and Vieu's (2009) Theory of Artifacts: Mental Selection, Constitution, and Capacity Attribution

Borgo and Vieu (2009) develop a formal ontology of artifacts compliant with the DOLCE upper ontology that rests on three key notions: mental selection, constitution, and capacity attribution. For readability, we cite their work by page number.

As a preliminary, we outline DOLCE's theory of qualities (Borgo & Masolo, 2010), especially the terms "(individual) quality," "quality space," and "quale," as they are important for understanding capacity attribution. A quality is a property

particular of a particular entity (e.g., the color of this particular rose). Quality types partition qualities: the color of this rose, but not its size, instantiates the color quality type. A quality space (e.g., the "color space") classifies qualities of the same quality type: it is the mereological sum of all the DOLCE:quality regions that are related to a certain quality type. A quale (e.g., a specific redness) is a "value" that a quality has in virtue of its position within a quality space.

First: mental selection ("intentional selection" in Borgo and Vieu's terms). Contrary to popular belief, they think that mental selection alone—even without physical modification—can specify the intentional dimension of artifacts: "we do not see the action of physical modification as an essential aspect of the creation of an artefact. [. . .] Artefacts are, *in nuce*, created entities in which 'created' refers to a mental event, not to a physical modification" (p. 292). Their notion of mental selection also distinguishes between artifacts and by-products: "*residues*, such as sawdust, are intentionally processed but not intentionally selected for having certain properties and use" (Borgo & Masolo, 2010).

Second: constitution (see also Vieu et al., 2008). Borgo and Vieu maintain that constitution (or the "constitution view of production," in our terms) explains the alleged "creation" of an artifact. They critique alternative views that treat "artefactuality as a property that physical endurants may or may not have" (p. 293), which aligns with our "continuity view of production." They argue: "by not granting artefacts an ontological status, it would not do justice to the notion of creation [. . .]. We are thus confronted with two co-located entities, the artefact and the underlying physical object" (Vieu et al., 2008). Their theory finds support in DOLCE's "*multiplicative approach*: it assumes that different entities can be co-located in the same space-time" (p. 285).

Third: capacity attribution. Before the creation of an artifact, the physical endurant bears "a single individual quality named *capacity* that characterizes all the capacities the physical endurant has. [. . .] This quality maps into a quale that is a region [. . .] in the *capacity space*" (p. 294). Borgo and Vieu illustrate this quality-based view of capacities with an example: "the capacity of this pen now has the quale of writing finely in black when drawn over paper, fitting in one's hand when grasped, and making a certain noise when it contacts the table" (ibid.). They acknowledge that the structure of the capacity space is complex and its detailed study is left for future work.

Borgo and Vieu characterize artifacts in terms of capacity attribution: "In addition to the capacity possessed by any physical endurant [footnote: We assume that an artefact's capacity is inherited from its constituting entity.], artefacts also have an *attributed capacity*, another quality associated with qualia in the *same* [capacity] space" (p. 294). They also explain the relationship between (unattributed) capacities and attributed capacities: "Although capacity and attributed capacity map into the same space of qualia, the former remains a physical quality whereas the latter is an intentional quality as it is dependent on the intentions of the creator at the time of the creation event" (p. 295).

We can illustrate Borgo and Vieu's theory with Example 2: at time t_2, $\mathbf{pebble_2}$ is intended to be used to keep papers in place. Before time t_2, $\mathbf{pebble_2}$ bears the (unattributed) capacity ($\mathbf{capacity_{pbl2}}$), a physical quality of $\mathbf{pebble_2}$ mapping into a quale (e.g., of blocking water flow), a subregion of the capacity space. At time t_2 (when mentally selected), $\mathbf{pebble_2}$ constitutes a new material entity $\mathbf{paperweight_2}$, which bears the attributed capacity $\mathbf{capacity_{pw2}}$, an intentional quality of $\mathbf{paperweight_2}$ that maps into the quale of keeping papers in place—a subregion of the same capacity space. For Borgo & Vieu, $\mathbf{paperweight_2}$ is an artifact. This aligns with their summary: "The paperweight is the result of some agent *intentionally selecting* a pebble and *attributing* to it certain capacities. The artefact itself is the new entity whose physical realization is the selected object and which has *attributed capacities*" (p. 293).

Borgo and Vieu's theory and ours share key ideas: the intentional dimension of artifacts can be specified by mental selection only, without physical modification, and being an artifact is characterized by a new property of the bearer—an attributed capacity in their theory and an intentional realizable entity in ours.

However, their theory differs greatly from ours in other respects. First, their notion of an artifact encompasses both canonical artifacts and usefacts: $\mathbf{paperweight_2}$ in Example 2 (usefact and natural object) is an artifact constituted by $\mathbf{pebble_2}$ and bearing $\mathbf{capacity_{pbl2}}$. Second, they endorse the constitution view of production, taking seriously the idea that artifacts are by nature "created." While our realizable-centered approach to artifacts is developed under the continuity view of both production and use—which may involve a somewhat counterintuitive construal of "production"—Borgo and Vieu's constitution view yields similarly counterintuitive results, such as the "creation" of $\mathbf{paperweight_2}$ (criticized by Kassel, 2010; see Section 2.2).

Despite these differences, our realizable-centered approach—particularly the notions of a canonical artifact and a usefact—can be reconstructed within Borgo & Vieu's framework, which assumes the constitution view of both production and use. To demonstrate this, we translate our novelty notion for realizable entities into their capacity-based theory.

The notion of a realizable entity approximates the notions of capacity and the quale into which it maps. Thus, an intentional realizable entity (e.g., $\mathbf{d_2}$ in our analysis of Example 2) approximates an attributed capacity and its quale (e.g., $\mathbf{capacity_{pw2}}$ and the quale of keeping papers in place).

To translate the notion of a novel realizable entity into Borgo & Vieu's constitution view of both production and use, we focus on their discussion of the inheritance of capacities through constitution: "The capacity of physical endurants

is inherited through constitution, in the sense that the quale of the capacity of the constituted entity includes that of the constituting entity [...]. Note that the two qualia need not be identical. The capacity of a physical object may include shape-based dispositions, while the capacity of the amount of matter constituting it cannot" (p. 299).

By extending this account of capacity inheritance via constitution, we can characterize canonical artifacts and usefacts in terms of capacities. For canonical artifacts, the quale of the capacity of the constituted canonical artifact *is a proper super-region of* the quale of the capacity of the constituting entity. Consider Example 1, where at time t_1, the quale of the capacity of the constituted $\mathbf{pot_1}$—as introduced in Example A of Section 2.2—includes the quale of containing liquid, whereas the quale of the capacity of the constituting $\mathbf{clay_1}$ does not. For usefacts, by contrast, the quale of the capacity of the constituted usefact *is a subregion of* the quale of the capacity of the constituting entity. In Example 2, $\mathbf{paperweight_2}$ is a usefact because the quale (including keeping papers in place) of $\mathbf{capacity_{pw2}}$ of $\mathbf{paperweight_2}$ is a subregion of the quale of $\mathbf{capacity_{pbl2}}$ of $\mathbf{pebble_2}$.

Based on this discussion, we analyze the novelty of a capacity in terms of the inclusion relation between qualia of capacities: we define the terms "novel capacity," "novel attributed capacity," and "physical canonical artifact" (aligning with the terms "novel realizable entity," "novel intentional realizable entity," and "material canonical artifact," respectively) as follows:

novel capacity $=_{\text{def.}}$ A capacity c such that the quale of c is a proper super-region of the quale of the capacity of the material entity that constitutes the bearer of c.

novel attributed capacity $=_{\text{def.}}$ An attributed capacity that is a novel capacity.

physical canonical artifact $=_{\text{def.}}$ A DOLCE:non-agentive physical object that bears a novel attributed capacity.

We remark that the term "material entity" in the definition of the term "novel capacity" refers to a constituting entity, following Borgo & Vieu (p. 297). It denotes a class uniting DOLCE:*Amount of matter* (e.g., an amount of clay) and DOLCE:*Non-agentive physical object* (e.g., pebbles).

We define the relation "is non-novel because of" between capacities and the term "physical usefact" (aligning with the relation "is non-novel because of" between realizable entities and the term "material usefact," respectively) as follows:

A capacity c is non-novel because of a capacity c'

$=_{\text{def.}}$ The quale of c is a subregion of the quale of c' of the material entity that constitutes the bearer of c.

physical usefact $=_{\text{def.}}$ A DOLCE:non-agentive physical object that bears an attributed capacity which is non-novel because of some attributed capacity that is not a novel attributed capacity.

This reformulation shows that, despite being developed under the continuity view of both production and use, our realizable-centered approach can be adapted to the constitution view of both production and use (which is adopted by Borgo & Vieu). This reformulation supports the claim that our approach is adaptable to both non-continuity views of production and/or use, and hence, to both monolithic and hybrid approaches to production and use.

7.2 Other Theories of Artifacts in Philosophy and in Formal Ontology

7.2.1 The Continuum Problem of Natural Objects and Artifacts in Philosophy. Our realizable-centered approach to artifacts builds on many philosophical accounts of artifacts (see e.g., Sections 3.2 and 3.3). Here, we focus on a classical problem of artifacts in philosophy: the continuum problem of natural objects and artifacts, which concerns demarcating a clear boundary between the two (more precisely, canonical artifacts in our terms). For instance, consider whether the following entities are natural objects or artifacts: seedless grapes (Sperber, 2007), synthetically produced chemical elements (e.g., technetium), paths, and ant hills—see Koslicki (2018, ch. 8) for detailed discussion. Preston (2022a) also asks: is this shell, originally on the beach but later used at home to keep papers in place (as a paperweight) after washing, polishing or coloring, a natural object or an artifact?

Philosophers address the continuum problem in two main ways. Some argue that, due to the complexities of the problem, the artifact category cannot be defined in a theoretically unifying way (Güngör, 2023, 2026; Preston, 2022b; Sperber, 2007).

Others propose alternatives to the traditional natural object—artifact dichotomy. For example, Dipert (1993) introduces three kinds of (material) objects:

- "instrument": a natural object intentionally used for a specific purpose ("an object that has been intentionally used in intentional activity"; p. 24). (Dipert also considers "contemplated instruments": natural objects intended to be used but without actual use. Borgo & Vieu (2009) point out that their notion of an artifact accommodates this idea.)
- "tool": an instrument intentionally and physically modified for a specific purpose ("intentionally modified instrument"; p. 27).
- "artifact proper" or simply "artifact": "an intentionally modified tool whose modified properties were intended by the agent to be recognized by an agent at a later time as having been intentionally altered for that, or some other, purpose" (pp. 29–30).

Our approach does not directly address the continuum problem but offers a perspective that clarifies it. First, the continuum problem typically concerns kinds of natural objects and artifacts (e.g., is *Seedless grape* a subclass of *Natural object* or *Artifact*?), whereas our approach leaves aside domain-specific artifact-related classes (e.g., *Pot*, *Paperweight*, *Doorstop* and *Amulet*), mentioning them for illustrative purposes. Indeed, a meticulous ontological analysis of such classes requires distinguishing artifact kind(s) from (specific) kinds of artifacts (see Section 2.2).

Second, our approach aligns with both solutions to the continuum problem. In the spirit of the first solution, we avoid using the term "artifact" and positing the class *Artifact*, as this term has been very differently used in different domains. At the same time, in the spirit of the second solution, we introduced the notions of a canonical artifact and a usefact: "material usefact" corresponds to Dipert's "contemplated instrument," while we do not introduce equivalents to Dipert's notions of a tool and an artifact, as our notion of a canonical artifact seeks to capture traditional philosophical understandings of artifacts (e.g., Hilpinen, 1992) without relying on the elusive notion of physical modification, a key source of the continuum problem.

Third, our approach to artifacts does not resolve the continuum problem but reframes it in realizable-based terms. If "artifact" in the continuum problem refers to canonical artifacts, the problem of natural reduces to distinguishing canonical artifacts from usefacts (is an entity a canonical artifact or a usefact?), then to distinguishing novel from non-novel realizable entities (is a realizable entity involved in this canonical artifact or usefact novel or not?), and ultimately to the individuation of realizable entities (is there a realizable entity because of which this realizable entity is non-novel or not?).

7.2.2 Theories of Artifacts in Formal Ontology. We now compare our realizable-centered approach to artifacts with other formal ontological theories, excluding Borgo and Vieu's (2009), which we examined in Section 7.1.

We begin with Borgo et al.'s (2014a) work, which provides an overview of existing theories of technical artifacts in formal ontology. They identify a "fundamental choice in ontology structuring" for technical artifacts: defining them "via a constitution relation" (the constitution view of production/use in our terms) or "via an intentional property" (ibid., p. 232). We initially took the latter path by developing the notion of an intentional realizable entity and applying it to characterize canonical artifacts and usefacts under the continuity view of both production and use. However, we also showed that our approach can be reformulated under the constitution view of both production and use (see Section 7.1).

Borgo et al. (2014a) highlight three definitions of "technical artifact": the "ontological definition" (attributed to Borgo & Vieu, 2009), the "engineering definition" and the "technological definition"; see also Borgo et al.'s (2014b) formalization of these three definitions in linear logic. They also discuss Kassel's (2010) theory of artifacts and technical artifacts. Since the ontological definition was covered in Section 7.1, we focus on the engineering definition, the technological definition and Kassel's theory.

First, as for the engineering definition, Kitamura and Mizoguchi (2010) say that a technical artifact is a material entity that comes into being through an "intentionally performed production process": roughly, a process in which (i) an agent physically changes a material entity with the goal that the produced entity will manifest an intended behavior in some generic situation and (ii) the produced entity can manifest this behavior to some degree. While "behavior" warrants ontological analysis in engineering (Borgo et al., 2006; Compagno, 2025; Compagno & Borgo, 2024b), this notion of a technical artifact aligns with our framework as "a material canonical artifact that bears some novel intentional *intrinsic disposition*" (not merely a novel intentional *realizable entity*, as per Definition 2 in Section 3.3), since it emphasizes production, the producer's intention, and physical change.

Second, as for the technological definition, Houkes & Vermaas (2014) define an artifact using two conceptual pillars: *make plan* (Houkes & Vermaas, 2009a, 2014) and *use plan* (Houkes & Vermaas, 2010). Borgo et al. (2014a) explain: "A use plan for a physical object is a goal-directed series of considered actions, where some of the actions involve interacting with the object" (p. 223, italics omitted). A make plan is defined as: "a use plan for a set of materials and a set of tools

that has the aim to create a physical object *a* that meets a specific physical description (. . .). Carrying out a make plan for a physical object *a* counts as producing *a*" (ibid., p. 224).

For Houkes and Vermaas, an artifact is a material entity (i) which is created through the carrying out by an agent of a make plan for a material entity with a specific physical description and (ii) for which a use plan exists. To illustrate this definition, $\mathbf{clay_1}$ at time t_1 is an artifact (Example 1) but $\mathbf{pebble_2}$ at time t_2 or t_2' is not an artifact, as it is a material entity with a use plan but without a relevant make plan having been carried out (Examples 2 and 5).

Houkes and Vermaas's theory differs from ours in several ways. First, it centers on the notion of a plan, which we exclude from scope due to its highly complex character (Ardisson et al., 2025; Barton et al., 2019; Duncan et al., 2024). Second, their theory adopts the broad interpretation of "use," treating production as a kind of use, as a make plan is defined as a kind of use plan. Houkes & Vermaas's "use plan" corresponds to our "usefactual realizable entity" and their "make plan" corresponds to a more specific notion of a usefactual realizable entity that is associated with "use for production" (e.g., $\mathbf{d_0}$ borne by $\mathbf{clay_1}$ at time t_0 in Example 7; see Section 6.3). From a realizable-centered perspective, the notion of an artifact in the technological definition may be understood as "a material canonical artifact that bears some novel intentional intrinsic disposition" because it relies on physical description and production.

Third, Kassel (2010) develops a theory of artifacts and technical artifacts within the DOLCE upper ontology. For him: "an artefact is an entity (i) that is produced with prior intention and (ii) successfully becomes a member of the kind of artefact produced" (ibid., p. 227). A technical artifact is a material entity with a function, where a function is "an ascribed capacity which enables the realization of an action" (ibid., p. 228, italics omitted) and a capacity is "a potential which an entity possesses (at least partially intrinsically) and which is exploited by that entity for the realization (as an agent) of an action, i.e., rendering the latter possible" (ibid.).

Kassel's theory share similarities with our realizable-centered approach. For instance, he endorses the continuity view of production (under which our approach is developed), and states (ibid., p. 242): "we consider the artefact and the physical object to be a single entity, whereas B&V [Borgo & Vieu (2009)] consider them to be two co-localized entities." Additionally, Kassel characterizes technical artifacts in terms of ascribed potentials (i.e., functions), borne at least partially intrinsically, whose realizations are actions—and, in this sense, his "potential" would be synonymous with our "realizable entity."

Nevertheless, Kassel's "artifact" is narrower than our "material canonical artifact," even when restricted to material entities. His definition emphasizes the producer's intention regarding a specific artifact kind. Thus, Kassel's material artifact may be interpreted in our approach as "a material canonical artifact that bears some design function" (where "design function" is understood according to Definition 11 in Section 4.1), *pace* Borgo et al.'s (2014a) analysis that Kassel's definition is a variant of the engineering definition.

We now address other theories of artifacts in formal ontology not discussed by Borgo et al. (2014a), some of which have an interdisciplinary character.

Garbacz (2013) proposes a family resemblance approach to artifacts, drawing on the notion of a "frame" in cognitive science, whose main role is to represent concepts. Inspired by the idea of a product life cycle, he considers artifacts as "objects-with-histories," characterized by five frames: design, production, use, service, and disposal. He argues that this framework sheds light on the multifaceted problem of artifact categorization.

Our realizable-centered approach partially captures Garbacz's (2013, p. 441) idea of "tracing the changes of [the ontological status of artifacts] through life-cycles"—cf. Evnine's (2022) "historicity" and Raven's (2025) "dynamics" of artifacts. For instance, the canonical artifact $\mathbf{clay_1}$ at time t_1' becomes a usefact as well (in Example 3), acquiring a dual artifact status, in the sense of production and in the sense of use. Additionally, his proposal to classify artifacts by "properties that are important from the point of view of maintenance or disposal" (ibid.) could enrich our approach. To explore this, it is useful to investigate within our framework the notion of malfunction(ing) (roughly: an entity's failure to perform a function in the way it is supposed to; Baker, 2009, Compagno, 2025; Compagno & Borgo, 2024a; Jansen, 2018; Jespersen & Carrara, 2011, 2013), by analyzing it through Vetter's (2015) notion of an iterated potentiality (Koslicki, 2023; Koslicki & Massin, in press). For this line of inquiry, see Toyoshima & Jansen (2026).

Troquard (2014) develops a formal conceptual framework ("pre-ontology" in his terms) in first-order logic "to support the development of proper formal ontologies of artefacts [physical or institutional] and tools" (ibid., p. 120). He emphasizes that "[a]rtefacts have designed functions and realized functions" (ibid.), where "[a] function can be any state of affairs [. . .] towards which an activity may be directed, or towards which an activity may be desirably directed" (ibid., p. 125). He also states: "A function is agent specific when its guard involves the bringing about the trying of some specific agent" (ibid., p. 126).

Despite relying on the notion of a function, Troquard's theory may contribute to formally underpin our realizable-centered approach to artifacts. In particular, it may help in future work to formalize intentional realizable entities. First, his notion of a function is broad enough to align with our notion of a goal. Second, his explanation of "realized functions"

aligns with our analysis of the intentional dimension of artifacts: "Objects can be elected to the status of artefact by the mere selection by an agent and without physical modification" (ibid., p. 128).

Masolo & Sanfilippo (2020) present a formal framework for representing and comparing different theories of technical artifacts. Their work analyzes the intentional dimension of artifacts by identifying different "modalities" of characterizing artifact types without recourse to intentional properties. This approach is largely orthogonal to our realizable-centered approach, as it (i) adopts an engineering perspective focusing on design specifications, requirements, and make plans; and (ii) is inspired by cognitive theories of categorization rather than the largely realist setting underlying our approach.

Weigand et al. (2021) provide an ontological analysis of artifacts from the viewpoint of design science grounded in the UFO upper ontology. They introduce the following foundational terms for their general ontology of artifacts—including information systems (ibid., p. 5):

> "artificial object": a physical object made by human agents. [Example: a footprint in the sand, production waste, hammers, cars and software.]
>
> ("physical object" here includes abstract artifacts like software, though social entities are excluded.)
>
> "natural object": a physical object that is not an artificial object. [Example: blood produced by the human body, a pebble at the beach and a beaver dam (assuming that beavers lack intentions).]
>
> "technical object": a non-agentive physical object intentionally created, usually for practical use. It "has *capacities* that are *realized* in its use." [Example: hammers, cars, software and a beaver dam (assuming that beavers have intentions).]
>
> "instrument": a physical object with the role of being used in an event. [Example: a shell used for drinking water, stars used to navigate at sea, live leeches used in medicine, a pebble thrown to kill a bird and a pebble that is cleaned and moved to serve as a doorstop as intended.]

We can compare Weigand et al.'s ontology with ours. First, artificial objects encompass our "canonical artifacts" and by-products (see Section 3.2). Second, technical objects align with our "canonical artifacts," since they are characterized by capacities realized in use. Material kinds of technical objects (excluding e.g., software) can be understood as material canonical artifacts. Third, instruments correspond approximately to our "usefacts" (with actual use). Given the statement that "capacities are not necessarily limited to the designed capacities," as "a printer can be used as a doorstop" (ibid., p. 10), material instruments can be interpreted as material usefacts bearing usefactual realized entities.

Given the affinity between Weigand et al.'s and our views of artifacts, it is instructive to see their ontological analysis of what they call "text objects":

> A text object such as the blue book on my desk is a technical object where the capacity (the written content) is manifested in the use (the reading). Text is to be understood in a wide sense, i.e., a variety of information encoding modes. Any text object has a physical basis (e.g., paper, disk block), a structure (of signs), a capacity (meaning) and an intended use.
>
> (Weigand et al., 2021, p. 14, boldface omitted)

However, this excerpt is problematic for two reasons. First, the phrase "text object such as the blue book" conflates between "physical texts (aka: text tokens) and abstract texts (aka: texts)" (Garbacz, 2016, p. 348). Second, the terms "capacity (the written content)" and "capacity (meaning)" require clarification, e.g., as the capacities to provide content or meaning.

Despite these issues, if we assume that Weigand et al.'s "technical objects" can include both material and abstract entities and can have capacities, their discussion suggests that, assuming the primitive term "abstract entity," we could define "abstract canonical artifact" as "an abstract entity bearing a novel intentional realizable entity." Under this definition, texts—more precisely, Garbacz's (2016) "abstract texts"—can be classified as a subtype of abstract canonical artifacts.

Further investigation is clearly warranted for the development of a full-fledged, realizable-centered ontology of texts. For example, Weigand et al. (2021, p. 14) state: "text objects [...] have a representational function. [...] For natural language text objects, this representational function has its basis in the language community." This implies that an ontological analysis of texts will require an ontology of linguistic community (cf. Evnine, 2025; Irmak, 2019). While a semiotic approach to language attracts attention in formal ontology (Bateman, 2019; Sowa, 2015), a useful starting point for our realizable-based analysis of texts is Dowland et al.'s (2023) dispositional account of language and linguistic community

in BFO: roughly, a language is an aggregate of linguistic competences (which are BFO:dispositions) and a linguistic community is a maximal collection of people bearing linguistic competences for the same language.

Finally, Fiegenbaum (2024) formalizes artifacts within the General Formal Ontology (GFO; Herre et al., 2007; Loebe et al., 2022). Her notion of an artifact aligns with our notion of a material canonical artifact, as she states: "Artefacts are material objects made by intentional agents with an intention to build an artifact of a specific artifact kind" (Fiegenbaum, 2024, p. 3). However, her "artifact" may be conceptually narrower than our "material canonical artifact," as it is restricted to the intention to produce an entity of a specific kind. In addition, she analyzes the intentional dimension of artifacts in terms of mental representation, whereas we ground our analysis in a realizable-based mental ontology of belief, desire and intention (see Section 2.3).

8 Conclusion

We have provided a theoretical foundation for a formal ontology of artifacts anchored to the ontology of realizable entities. This realizable-centered approach to artifacts is motivated by limitations of traditional, function-based accounts of artifacts (which focus mainly on technical artifacts) and the need for further investigation into the intentional dimension of artifacts. For this purpose, we introduced the notions of a canonical artifact and a usefact, and provided a realizable-centered characterization of them, assuming a realizable-based view of intention as an intrinsic disposition. We argued that our approach is more general than three prominent function-based accounts of artifacts which rest on design functions, proper functions, and system functions. We also demonstrated the adaptability of our framework to BFO, illustrating its flexibility and applicability.

Our approach opens multiple avenues for further research. Some directions have been outlined earlier (see e.g., Sections 6 and 7.2.2). From a theoretical viewpoint, it is important to extend our approach to abstract artifacts (see Sections 1.3 and 7.2.2). Noteworthy examples include software (Begley, 2024; Colburn, 1999; Irmak, 2012), which is crucial in information systems (Duncan, 2017; Eden & Turner, 2007; Keet, 2020; Wang et al., 2014) and presents challenges in analyzing ontologically its functioning and malfunctioning (de Haas & Houkes, 2025; Floridi et al., 2015; Hurshman, 2024); fictional characters, which are vital for an ontological approach to the Digital Humanities (Masolo et al., 2025; Sanfilippo et al., 2024) and also pose ontological puzzles regarding their functioning and malfunctioning (Terrone, 2023); artworks (see the relevant references in Section 1.3; especially for discussions on their functioning and malfunctioning, see Franda & Souman, 2025); and apparently "authorless" artifacts produced by artificial intelligence (Irmak, 2024a; van Woudenberg et al., 2024).

Additionally, we can strengthen our approach by deepening the ontological analysis of faith-based artifacts based on an ontological analysis of religious and spiritual belief (Schulz & Jansen, 2018); by connecting our framework with the notion of an affordance (Cosentino, 2021), particularly with a realizable-based analysis of affordances (Toyoshima et al., 2022a); and by developing a realizable-based representation of complex canonical artifacts (e.g., cars), their components (e.g., car engines) and the relationship between them. A mereology of realizable entities will be useful in analyzing the ontological structure of complex canonical artifacts (assuming that they are composed of simple canonical artifacts), although a mereological study of realizable entities remains little investigated in philosophy (Austin et al., 2024) and in formal ontology (Barton et al., 2017).

From a practical viewpoint, it will be worthwhile to apply our realizable-centered approach to artifacts to solidify the foundations of existing domain ontologies dealing with artifacts. Such domain ontologies include:

- FoodOn (Dooley et al., 2018): a BFO-compliant ontology of food and food production, whose class *Food product* (http://purl.obolibrary.org/obo/FOODON_00001002) needs to be explored further (Toyoshima et al., 2025).
- A suite of BFO-based ontologies of product life cycle, where the term "product" is treated as synonymous with "artifact" (Otte et al., 2019; see also Section 5.1.2).
- A suite of manufacturing ontologies in the context of BFO-aligned Industrial Ontology Foundry (IOF; Smith et al., 2019; Drobnjakovic et al., 2022; see also Section 5.1.2).
- A BFO-compliant reference ontology for industrial maintenance (Karray et al., 2019).
- The CIDOC Conceptual Reference Model (CIDOC-CRM; Bekiari et al., 2024; see also Bruseker et al., 2017): a standardly used ontology for cultural heritage whose foundation warrants strengthening and extension (Beretta, 2021; Sanfilippo et al., 2020).
- An ontology of archeological investigations compliant with CIDOC-CRM (Hacıgüzeller et al., 2021; Lombard et al., 2022), in light of a growing awareness of the reuse of archeological data (Huggett, 2018) and the increasing role of formal ontologies in archeological studies (Cardinal, 2019; Dallas, 2009; Niccolucci et al., 2015), especially concerning artifacts (Almeida & Costa, 2021). For this line of study, see Toyoshima & Delley (2026), motivated

by the limitations in traditional function-based classifications of archeological artifacts (Loughmiller-Cardinal & Cardinal, 2020).

Acknowledgments

The authors extend our gratitude to Barry Smith for his valuable feedback on our preceding works, which helped us write Section 5. The research was conducted in cooperation with the Swiss Center for Ontological Research (SCOR). The authors also thank several anonymous reviewers for their helpful comments.

ORCID iDs

Fumiaki Toyoshima https://orcid.org/0000-0002-4690-1221
Adrien Barton https://orcid.org/0000-0001-5500-6539

Funding

This work forms part of the project "An Ontology of Production, Products, and By-Products" (2023–2027), funded by the Swiss National Science Foundation (SNSF; grant no. 212493). FT acknowledges financial support from SNSF.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration on Generative AI

During the preparation of this work, the authors used AI-based tools (including Le Chat from Mistral AI and ChatGPT) for grammar and spelling checks, as well as for paraphrasing and rewording. All outputs were carefully reviewed and edited by the authors, who take full responsibility for the content of this publication.

Notes

1. This paper results from a substantial extension and generalization of our works (Toyoshima et al., 2024a, 2024b) presented in the 10th Joint Ontology Workshops (JOWO, 2024). In particular, these previous works assume the framework of the upper ontology Basic Formal Ontology (BFO; Arp et al., 2015; Otte et al., 2022); whereas, by elaborating the general notion of a realizable entity, this paper aims to contribute to developing an "ontological module" (Ben Abbès et al., 2012; Khan & Keet, 2015) for representing artifacts that is "foundation-agnostic" (Grüninger & Katsumi, 2019), i.e., that can allow for the usage of different foundational frameworks by different ontology users.
2. Definition 1 is an elaborated version of Toyoshima et al.'s (2024a, p. 6) definition of the same term as "a realizable entity that comes into being for a specific goal through an intentional act", as the former definition rests on a detailed account of the notion of a goal (see Section 2.3).
3. We note that the term "determined by" used here should be different from the relation "determined by" from the BFO-compliant Relation Ontology (RO; Smith et al., 2005): "s determined by f if and only if s is a type of system, and f is a material entity that is part of s, such that f exerts a strong causal influence on the functioning of s, and the removal of f would cause the collapse of s" (http://purl.obolibrary.org/obo/RO_0002507).
4. Definition 3 presents a terminologically simplified rendition of Toyoshima et al.'s (2024a, p. 8) definition of the same entity.
5. In our previous works (Toyoshima et al., 2024a, 2024b), we argued that our realizable-based analysis of canonical artifacts is adaptable to the non-continuity view of production. Our reasoning was that when a realizable entity comes into being simultaneously with its bearer, it is "trivially novel", since neither the bearer *nor any of its realizable entities* existed beforehand. However, we now find the notion of trivial novelty of realizable entities problematic. This is because it fails to account for usefacts under the non-continuity view of use, as bearing a "non-novel" intentional realizable entity is a necessary condition for a material entity to be a usefact (see Section 3.4 for details). Our earlier investigation was limited in that respect, partly because we did not consider philosophical views of diachronic identity *with respect to use*, as is illustrated by Example B in Section 2.2.
6. Definition 5 is a generalized version of Toyoshima et al.'s (2024a, p. 10) definition of the same relation, as the latter definition relies on the BFO notion of an independent continuant.
7. Definition 7 is a generalized version of Toyoshima et al.'s (2024a, p. 8) definition of the same relation, as the latter definition relies on the BFO notion of an independent continuant.
8. The BFO-compliant Common Core Ontology (CCO; Jansen et al., 2024; The Common Core Ontologies Repository, 2024) defines the term "intentional act" as "an act in which at least one agent plays a causative role and which is prescribed by some directive information content entity held by at least one of the agents". This CCO definition of the term "intentional act" is nevertheless too narrow to characterize the notion of an intentional act involved in artifactual capacities, as it would not accommodate mental selection.

References

Abell, C. (2012). Art: What it is and why it matters. *Philosophy and Phenomenological Research*, *85*(3), 671–691. https://doi.org/10.1111/j.1933-1592.2011.00498.x

Almeida, B., & Costa, R. (2021). Ontoandalus: An ontology of Islamic artefacts for terminological purposes. *Semantic Web*, *12*(2), 295–311. https://doi.org/10.3233/SW-20038

Almeida, J. P. A., Falbo, R. A., & Guizzardi, G. (2019). Events as entities in ontology-driven conceptual modeling. In A. H. F. Laender, B. Pernici, E.-P. Lim, & J. P. M. de Oliveira (Eds.), *Proceedings of the 38th international conference on conceptual modeling (ER 2019), salvador, Brazil, November 4–7, 2019. Lecture notes in computer science* (Vol. 11788, pp. 469–483). Springer.

Ardisson, P., Dikmen, F., Moltmann, F., & Müller, K. (2025). The role of plans for qua-events and their effects on part-structure. In T. P. Sales, C. Masolo, & C. E. Keet (Eds.), *Proceedings of the 15th international conference on formal ontology in information systems (FOIS 2025), online, September 4 and Catania, Italy, September 10–12, 2025* (pp. 79–93). IOS Press.

Arp, R., Smith, B., & Spear, A. D. (2015). *Building ontologies with basic formal ontology*. MIT Press.

Artiga, M. (2011). Re-organizing organizational accounts of function. *Applied Ontology*, *6*(2), 105–124. https://doi.org/10.3233/AO-2011-0091

Artiga, M. (2016). New perspectives on artifactual and biological functions. *Applied Ontology*, *11*(2), 89–102. https://doi.org/10.3233/AO-160166

Austin, C. J., Marmodoro, A., & Roselli, A., (Eds.) (2024). *Powers, parts and wholes: Essays on the mereology of powers*. Routledge.

Bahr, A. (2019). What the Mona Lisa and a screwdriver have in common. *Grazer Philosophische Studien*, *96*(1), 81–104. https://doi.org/10.1163/18756735-000057

Baker, L. R. (2007). *The metaphysics of everyday life: An essay in practical realism*. Cambridge University Press.

Baker, L. R. (2009). The metaphysics of malfunction. *Techné*, *13*(2), 82–92. https://doi.org/10.5840/techne20091328

Barton, A., Duncan, W., Toyoshima, F., & Ethier, J.-F. (2018a). First steps towards an ontology of belief. In L. Jansen, D. P. Radicioni, & D. Gromann (Eds.), *Proceedings of the 4th joint ontology workshops (JOWO 2018), Cape Town, South Africa, September 17–18, 2018. CEUR workshop proceedings* (Vol. 2205, pp. 1–5).

Barton, A., Grenier, O., & Ethier, J.-F. (2018b). The identity and mereology of pathological dispositions. In L. Cooper & P. Jaiswal (Eds.), *Proceedings of the 9th international conference on biological ontology (ICBO 2018), Corvallis, Oregon, U.S., August 7–10, 2018. CEUR workshop proceedings* (Vol. 2285, pp. 1–6).

Barton, A., Grenier, O., Jansen, L., & Ethier, J.-F. (2018c). The identity of dispositions. In S. Borgo, P. Hitzler, & O. Kutz (Eds.), *Proceedings of the 10th international conference of formal ontology in information systems (FOIS 2018), Cape Town, South Africa, September 17–21, 2018* (pp. 113–126). IOS Press.

Barton, A., Jansen, L., & Ethier, J.-F. (2017). A taxonomy of disposition-parthood. In A. Galton & F. Neuhaus (Eds.), *Proceedings of the 3rd joint ontology workshops (JOWO 2017), bozen-bolzano, Italy, September 21–23, 2017. CEUR workshop proceedings* (Vol. 2050, pp. 1–10).

Barton, A., Vieu, L., & Ethier, J.-F. (2019). Directing actions. In A. Barton, S. Seppälä, & D. Porello (Eds.), *Proceedings of the 5th joint ontology workshops (JOWO 2019), graz, Austria, September 23–25, 2019. CEUR workshop proceedings* (Vol. 2518, pp. 1–10).

Bateman, J. A. (2019). Ontology, language, meaning: Semiotic steps beyond the information artifact. In S. Borgo, R. Ferrario, C. Masolo, & L. Vieu (Eds.), *Ontology makes sense: Essays in honor of Nicola Guarino* (pp. 119–135). IOS Press.

Begley, K. (2024). Towards a realist metaphysics of software maintenance. In M. T. Young & M. Coeckelbergh (Eds.), *Maintenance and philosophy of technology: Keeping things going* (pp. 162–183). Routledge.

Bekiari, C., Bruseker, G., Canning, E., Michon, P., Doerr, M., Ore, C.-E., Stead, S., & Velios, A. (2024). *Definition of the CIDOC conceptual reference model v7.3 (Version v7.3)*. The CIDOC Conceptual Reference Model Special Interest Group.

Ben Abbès, S., Scheuermann, A., Meilender, T., & D'Aquin, M. (2012). Characterizing modular ontologies. In M. Donnelly & G. Guizzardi (Eds.), *Proceedings of the 7th international conference of formal ontology in information systems (FOIS 2012), Graz, Austria, July 24–27, 2012* (pp. 13–25). IOS Press.

Beretta, F. (2021). A challenge for historical research: Making data FAIR using a collaborative ontology management environment (OntoME). *Semantic Web*, *12*(2), 279–294. https://doi.org/10.3233/SW-200416

Beverley, J., Limbaugh, D., Merrell, E., Koch, P. M., & Smith, B. (2024). Capabilities: An ontology. In Í Oliveira, P. P. F. Barcelos, R. Calhau, C. M. Fonseca, & G. Righetti (Eds.), *Proceedings of the 10th joint ontology workshops (JOWO 2024), Enschede, Netherlands, July 15–19, 2024. CEUR workshop proceedings* (Vol. 3882, pp. 1–14).

Biccheri, L., Ferrario, R., & Porello, D. (2020). Needs and intentionality—An ontological analysis and an application to public services. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 125–139). IOS Press.

Borgo, S., Carrara, M., Vermaas, P., & Garbacz, P. (2006). Behavior of a technical artifact: An ontological perspective in engineering. In B. Bennett & C. Fellbaum (Eds.), *Proceedings of the 4th international conference on formal ontology in information systems (FOIS 2006), Baltimore, Maryland, USA, November 9–11, 2006* (pp. 214–225). IOS Press.

Borgo, S., Ferrario, R., Gangemi, A., Guarino, N., Masolo, C., Porello, D., Sanfilippo, E. M., & Vieu, L. (2022). DOLCE: A descriptive ontology for linguistic and cognitive engineering. *Applied Ontology*, *17*(1), 45–69. https://doi.org/10.3233/AO-210259

Borgo, S., Franssen, M., Garbacz, P., Kitamura, Y., Mizoguchi, R., & Vermaas, P. E. (2014a). Technical artifact: An integrated perspective. *Applied Ontology*, *9*(3–4), 217–235. https://doi.org/10.3233/AO-140137

Borgo, S., & Masolo, C. (2010). Ontological foundations of DOLCE. In R. Poli, M. Healy, & A. D. Kameas (Eds.), *Theory and applications of ontology: Computer applications* (pp. 279–295). Springer.

Borgo, S., Mizoguchi, R., & Kitamura, Y. (2016). Formalizing and adapting a general function module for foundational ontologies. In R. Ferrario & W. Kuhn (Eds.), *Proceedings of the 9th international conference on formal ontology in information systems (FOIS 2016), Annecy, France, July 6–9, 2016* (pp. 241–254). IOS Press.

Borgo, S., Porello, D., & Troquard, N. (2014b). Logical operators for ontological modeling. In P. Garbacz & O. Kutz (Eds.), *Proceedings of the 8th international conference on formal ontology in information systems (FOIS 2014), Rio de Janerio, Brazil, September 22–25, 2014* (pp. 23–36). IOS Press.

Borgo, S., Sanfilippo, E. M., & Terkaj, W. (2021). Capabilities, capacities, and functionalities of resources in industrial engineering. In E. M. Sanfilippo, O. Kutz, N. Troquard, T. Hahmann, C. Masolo, R. Hoehndorf, & R. Vita (Eds.), *Proceedings of the 7th joint ontology workshops (JOWO 2021), Bolzano, Italy, September 11–18, 2021. CEUR workshop proceedings* (Vol. 2969, pp. 1–12).

Borgo, S., & Vieu, L. (2009). Artefacts in formal ontology. In A. Meijers (Ed.), *Handbook of the philosophy of science. Handbook of philosophy of technology and engineering sciences* (Vol. 9, pp. 273–307). Elsevier.

Brodaric, B., & Grüninger, M. (2018). Particular types and particular dependence. In S. Borgo, P. Hitzler, & O. Kutz (Eds.), *Proceedings of the 10th international conference on formal ontology in information systems (FOIS 2018), Cape Town, South Africa, September 17–21, 2018* (pp. 19–32). IOS Press.

Bruseker, G., Carboni, N., & Guillem, A. (2017). Cultural heritage data management: The role of formal ontology and CIDOC CRM. In M. L. Vincent, V. M. López-Menchero Bendicho, M. Ioannides, & T. E. Levy (Eds.), *Heritage and archaeology in the digital age: Acquisition, curation, and dissemination of spatial cultural heritage data. Quantitative methods in the humanities and social sciences* (pp. 93–131). Springer.

Burek, P. (2006). Ontology of functions: A domain-independent framework for modeling functions. [Ph. D. Thesis] University of Leipzig, Germany. https://www.onto-med.de/sites/www.onto-med.de/files/files/uploads/Publications/2007/burek-p-2007-a.pdf. (Last accessed on April 3, 2026).

Burek, P., Loebe, F., & Herre, H. (2016). Fuel: Representing function structure and function dependencies with a UML profile for function modeling. *Applied Ontology*, *11*(2), 155–203. https://doi.org/10.3233/AO-160167

Cardinal, J. S. (2019). Sets, graphs, and things we can see: A formal combinatorial ontology for empirical intra-site analysis. *Journal of Computer Applications in Archaeology*, *2*(1), 56–78. https://doi.org/10.5334/jcaa.16

Carrara, M., Garbacz, P., & Vermaas, P. E. (2011). If engineering function is a family resemblance concept: Assessing three formalization strategies. *Applied Ontology*, *6*(2), 141–163. https://doi.org/10.3233/AO-2011-0090

Ceusters, W., & Ruttenberg, A. (2025). Towards representing change in the BFO. In T. P. Sales, C. Masolo, & C. E. Keet (Eds.), *Proceedings of the 15th international conference on formal ontology in information systems (FOIS 2025), online, September 4 and Catania, Italy, September 10–12, 2025* (pp. 94–108). IOS Press.

Ceusters, W., & Smith, B. (2015). Aboutness: Towards foundations for the information artifact ontology. In F. M. Couto & J. Hastings (Eds.), *Proceedings of the 6th international conference on biomedical ontology (ICBO 2015), Lisbon, Portugal, July 27–30, 2015, CEUR workshop proceedings* (Vol. 1515, pp. 1–5).

Colburn, T. R. (1999). Software, abstraction, and ontology. *The Monist*, *82*(1), 3–19. https://doi.org/10.5840/monist19998215

Compagno, F. (2025). Modelling of functions and malfunctions in industrial processes: An applied ontology approach. [Ph. D. Thesis] University of Trento, Italy, 2025. https://hdl.handle.net/11572/450850. (Last accessed on April 3, 2026).

Compagno, F., & Borgo, S. (2024a). Ontological analysis of malfunctions: Some formal considerations. In C. Trojahn, D. Porello, & P. P. F. Barcelos (Eds.), *Proceedings of the 14th international conference on formal ontology in information systems (FOIS 2024), online, July 8–9 and Enschede, Netherlands, July 15–19, 2024* (pp. 149–162). IOS Press.

Compagno, F., & Borgo, S. (2024b). Towards a formal ontology of engineering functions, behaviours, and capabilities. *Semantic Web*, *15*(2), 285–318. https://doi.org/10.3233/SW-223188

Compagno, F., Borgo, S., Sanfilippo, E. M., & Terkaj, W. (2023). Manufacturing resources, capabilities, and engineering functions: Towards an ontology-based integration. In N. Aussenac-Gilles, T. Hahmann, A. Galton, & M. M. Hedblom (Eds.), *Proceedings of the 13th international conference on formal ontology in information systems (FOIS 2023), Sherbrooke, Québec, Canada, July 17–20 and online, September 18–20, 2023* (pp. 272–287). IOS Press.

Cosentino, E. (2021). Artifacts and affordances. *Synthese*, *198*(suppl 17), 4007–4026. https://doi.org/10.1007/s11229-019-02297-4

Cummins, R. (1975). Functional analysis. *Journal of Philosophy*, *72*(20), 741–765. https://doi.org/10.2307/2024640

Currie, G. (1989). *An ontology of art*. Palgrave.

Dallas, C. (2009). From artefact typologies to cultural heritage ontologies: Or, an account of the lasting impact of archaeological computing. *Archeologia e Calcolatori*, *20*, 205–222.

Davidson, D. (1969). The individuation of events. In N. Rescher (Ed.), *Essays in honor of Carl G. Hempel* (pp. 216–234). Reidel.

Davies, D. (2024). *An ontology of multiple artworks*. Oxford University Press.

de Haas, J., & Houkes, W. (2025). Can't software malfunction? *Metaphysics*, *9*(1), 1–15. https://doi.org/10.5334/met.165

Dickie, G. (1969). Defining art. *American Philosophical Quarterly*, *6*(3), 253–256.

Dipert, R. R. (1993). *Artifacts, art works, and agency*. Temple University Press.

Dodd, J. (2000). Musical works as eternal types. *British Journal of Aesthetics*, *40*(4), 424–440. https://doi.org/10.1093/bjaesthetics/40.4.424

Donnelly, M. (2005). Relative places. *Applied Ontology*, *1*(1), 55–75. https://doi.org/10.3233/APO-2005-000001

Dooley, D. M., Griffiths, E. J., Gosal, G. S., Buttigieg, P. L., Hoehndorf, R., Lange, M. C., Schriml, L. M., Brinkman, F. S. L., & Hsiao, W. W. L. (2018). Foodon: A harmonized food ontology to increase global food traceability, quality control and data integration. *NPJ Science of Food*, *2*, 23. https://doi.org/10.1038/s41538-018-0032-6

Dowland, S. C., Smith, B., Diller, M. A., Landgrebe, J., & Hogan, W. R. (2023). Ontology of language, with applications to demographic data. *Applied Ontology*, *18*(3), 239–262. https://doi.org/10.3233/AO-230049

Drobnjakovic, M., Kulvatunyou, B(S), Ameri, F., Will, C., Smith, B., & Jones, A. (2022). The industrial ontologies foundry (IOF) core ontology. In E. M. Sanfilippo, M.-H. Karray, D. Kyritsis, & A. Sarkar (Eds.), *Proceedings of the 12th international workshop on formal ontologies meet industry (FOMI 2022), Tarbes, France, September 12–15, 2022. CEUR workshop proceedings* (Vol. 3240, pp. 1–13).

Duncan, W. D. (2017). Ontological distinctions between hardware and software. *Applied Ontology*, *12*(1), 5–32. https://doi.org/10.3233/AO-170175

Duncan, W. D., Diller, M., Dooley, D., Hogan, W. R., & Beverley, J. (2024). Concretizing plan specifications as realizables within the OBO foundry. *Journal of Biomedical Semantics*, *15*(1), 15. https://doi.org/10.1186/s13326-024-00315-0

Eden, A. H., & Turner, R. (2007). Problems in the ontology of computer programs. *Applied Ontology*, *2*(1), 13–36. https://doi.org/10.3233/APO-2007-026

Evnine, S. J. (2013). Ready-mades: Ontology and aesthetics. *British Journal of Aesthetics*, *53*(4), 407–423. https://doi.org/10.1093/aesthj/ayt033

Evnine, S. J. (2022). The historicity of artifacts: Use and counter-use. *Metaphysics*, *5*(1), 1–13. https://doi.org/10.5334/met.74

Evnine, S. J. (2025). The curated artifact: The case of languages. *Synthese*, *205*, 131. https://doi.org/10.1007/s11229-025-04960-5

Falguera, J. L., & Martínez-Vidal, C., (Eds.). (2020). *Abstract objects: For and against (synthese library: Volume 422)*. Springer.

Ferrario, R., & Oltramari, A. (2004). Towards a computational ontology of mind. In A. Varzi & L. Vieu (Eds.), *Proceedings of the 3rd international conference on formal ontology in information systems (FOIS 2004), Torino, Italy November 4–6, 2004* (pp. 287–297). IOS Press.

Ferreira Ruiz, M., & Hundertmark, F. (2024). What are the causal bases of dispositions? *Australasian Journal of Philosophy*, *103*(3), 814–831. https://doi.org/10.1080/00048402.2024.2408689

Fiegenbaum, H. (2024). Toward a formalization of artifacts in GFO. *arXiv preprint* arXiv:2409.13452v1.

Floridi, L., Fresco, N., & Primiero, G. (2015). On malfunctioning software. *Synthese*, *192*, 1199–1220. https://doi.org/10.1007/s11229-014-0610-3

Franda, F., & Souman, P. (2025). Why art cannot (technically) malfunction. *Synthese*, *206*, 10. https://doi.org/10.1007/s11229-025-05086-4

Friedel, D. (2021). Creating abstract objects. *Philosophy Compass*, *16*(10), e12783. https://doi.org/10.1111/phc3.12783

Garbacz, P. (2013). Artefacts and family resemblance. *Review of Philosophy and Psychology*, *4*(3), 419–447. https://doi.org/10.1007/s13164-013-0145-4

Garbacz, P. (2016). A formal ontology of texts. In R. Ferrario & W. Kuhn (Eds.), *Proceedings of the 9th international conference on formal ontology in information systems (FOIS 2016), Annecy, France, July 6–9, 2016* (pp. 345–358). IOS Press.

Garbacz, P. (2022). A new perspective on criteria of identity. *Synthese*, *200*(476). https://doi.org/10.1007/s11229-022-03954-x

Garbacz, P. (2023). A quest for identity criteria in computational ontologies. In N. Aussenac-Gilles, T. Hahmann, A. Galton, & M. M. Hedblom (Eds.), *Proceedings of the 13th international conference on formal ontology in information systems (FOIS 2023), sherbrooke, Québec, Canada, July 17–20 and online, September 18–20, 2023* (pp. 169–181). IOS Press.

Gardner, S. P. (2005). Ontologies and semantic data integration. *Drug Discovery Today*, *10*(14), 1001–1007. https://doi.org/10.1016/S1359-6446(05)03504-X

Grünbaum, T. (2008). Trying and the arguments from total failure. *Philosophia*, *36*(1), 67–86. https://doi.org/10.1007/s11406-007-9096-2

Grüninger, M., Chui, C., Ru, Y., & Thai, J. (2020). A mereology for connected structures. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 171–185). IOS Press.

Grüninger, M., & Katsumi, K. (2019). Foundationless ontologies. In A. Barton, S. Seppälä, & D. Porello (Eds.), *Proceedings of the 5th joint ontology workshops (JOWO 2019), Graz, Austria, September 23–25, 2019. CEUR workshop proceedings* (Vol. 2518, pp. 1–10).

Guarino, N., Baratella, R., & Guizzardi, G. (2022). Events, their names, and their synchronic structure. *Applied Ontology*, *17*(2), 249–283. https://doi.org/10.3233/AO-220261

Guizzardi, G. (2005). Ontological foundations for structural conceptual models. PhD thesis, University of Twente, Netherlands. Available online at https://research.utwente.nl/en/publications/ontological-foundations-for-structural-conceptualmodels. (Last accessed on April 3, 2026).

Guizzardi, G., Botti Benevides, A., Fonseca, C. M., Porello, D., Almeida, J. P. A., & Prince Sales, T. (2022). UFO: Unified foundational ontology. *Applied Ontology*, *17*(1), 167–210. https://doi.org/10.3233/AO-210256

Guizzardi, G., Guarino, N., & Almeida, J. P. A. (2016). Ontological considerations about the representation of events and endurants in business models. In M. La Rosa, P. Loos, & O. Pastor (Eds.), *Proceedings of the 14th international conference on business process management (BPM 2016), Rio de Janeiro, Brazil, September 18–22, 2016. Lecture notes in computer science* (Vol. 9850, pp. 20–36). Springer.

Guizzardi, G., Wagner, G., de Almeida Falbo, R., Guizzardi, R. S. S., & Almeida, J. P. A. (2013). Towards ontological foundations for the conceptual modeling of events. In W. Ng, V. C. Storey, & J. C. Trujillo (Eds.), *Proceedings of the 32nd international conference on conceptual modeling (ER 2013), Hong-Kong, China, November 11–13, 2018. Lecture notes in computer science* (Vol. 8217, pp. 327–341). Springer.

Güngör, A. (2023). Artifact concept pluralism. *Dialectica*, *77*(2), 123–151. https://doi.org/10.48106/dial.v77.i2.01

Güngör, A. (2026). Artworks, functions, and pluralism about 'artifact'. *Erkenntnis*, *91*, 409–425. https://doi.org/10.1007/s10670-024-00889-2

Hacıgüzeller, P., Taylor, J. S., & Perry, S. (2021). On the emerging supremacy of structured digital data in archaeology: A preliminary assessment of information, knowledge and wisdom left behind. *Open Archaeology*, *7*(1), 1709–1730. https://doi.org/10.1515/opar-2020-0220

Herre, H., Heller, B., Burek, P., Hoehndorf, R., Loebe, F., & Michalek, H. (2007). *General Formal Ontology (GFO)—A foundational ontology integrating objects and processes (Part I: Basic Principles) [Version 1.0.1]*. Technical report, Research Group Ontologies in Medicine (Onto-Med), Institute of Medical Informatics, Statistics and Epidemiology, University of Leipzig.

Hick, D. H. (2019). Using things as art. *Grazer Philosophische Studien*, *96*(1), 56–80. https://doi.org/10.1163/18756735-000060

Hilpinen, R. (1992). Artifacts and works of art. *Theoria*, *58*(1), 58–82. https://doi.org/10.1111/j.1755-2567.1992.tb01155.x

Hobbs, J., & Gordon, A. (2010). Goals in a formal theory of commonsense psychology. In A. Galton & R. Mizoguchi (Eds.), *Proceedings of the 6th international conference on formal ontology in information systems (FOIS 2010), Toronto, Canada, May 11–14, 2010* (pp. 59–72). IOS Press.

Holm, S. (2017). The problem of phantom functions. *Erkenntnis*, *82*(1), 233–241. https://doi.org/10.1007/s10670-016-9814-x

Hornsby, J. (1980). *Actions*. Routledge and Kegan Paul.

Houkes, W., & Vermaas, P. E. (2009a). Contemporary engineering and the metaphysics of artefacts: Beyond the artisan model. *Monist*, *92*(3), 403–419. https://doi.org/10.5840/monist200992323

Houkes, W., & Vermaas, P. E. (2009b). Produced to use: Combining two key intuitions on the nature of artefacts. *Techné*, *13*(2), 123–136. https://doi.org/10.5840/techne200913211

Houkes, W., & Vermaas, P. E. (2010). *Technical functions: On the use and design of artefacts*. Springer.

Houkes, W., & Vermaas, P. E. (2014). On what is made: Instruments, products and natural kinds of artefacts. In M. Franssen, P. Kroes, T. A. C. Reydon, & P. E. Vermaas (Eds.), *Artefact kinds: Ontology and the human-made world* (pp. 167–190). Springer.

Huggett, J. (2018). Reuse remix recycle: Repurposing archaeological digital data. *Advances in Archaeological Practice*, *6*(2), 93–104. https://doi.org/10.1017/aap.2018.1

Hurshman, C. (2024). Do opaque algorithms have functions? *Synthese*, *204*(91). https://doi.org/10.1007/s11229-024-04745-2

Ingthorsson, R. D. (2021). *A powerful particulars view of causation*. Routledge.

Irmak, N. (2012). Software is an abstract artifact. *Grazer Philosophische Studien*, *86*(1), 55–72. https://doi.org/10.1163/9789401209182_005

Irmak, N. (2019). An ontology of words. *Erkenntnis*, *84*(5), 1139–1158. https://doi.org/10.1007/s10670-018-0001-0

Irmak, N. (2021). The problem of creation and abstract artifacts. *Synthese*, *198*, 9695–9708. https://doi.org/10.1007/s11229-020-02672-6

Irmak, N. (2024a). Artifacts without authors: Generative artificial intelligence and the question of authorship. *Metaphysics*, *7*(1), 1–15. https://doi.org/10.5334/met.160

Irmak, N. (2024b). The mess we make: On the metaphysics of artifact kinds. *Erkenntnis*, *90*, 2003–2019. https://doi.org/10.1007/s10670-024-00789-5

Jansen, L. (2013). Artefact kinds need not be kinds of artefacts. In C. Svennerlind, A. Jan, & R. Ingthorsson (Eds.), *Johanssonian investigations: Essays in honour of Ingvar Johansson on his seventieth birthday* (pp. 317–337). Ontos Verlag.

Jansen, L. (2018). Functions, malfunctioning, and negative causation. In A. Christian, D. Hommen, N. Retzlaff, & G. Schurz (Eds.), *Philosophy of science. European studies in philosophy of science* (Vol. 9, pp. 117–135). Springer.

Jenkins, C. S., & Nolan, D. (2012). Disposition impossible. *Noûs*, *46*(4), 732–753. https://doi.org/10.1111/j.1468-0068.2011.00831.x

Jensen, M., De Colle, G., Kindya, S., More, C., Cox, A., & Beverley, J. (2024). The common core ontologies. In C. Trojahn, D. Porello, & P. P. F. Barcelos (Eds.), *Proceedings of the 14th international conference on formal ontology in information systems (FOIS 2024), online, July 8–9 and Enschede, Netherlands, July 15–19, 2024* (pp. 47–58). IOS Press.

Jespersen, B., & Carrara, M. (2011). Two conceptions of technical malfunction. *Theoria*, *77*(2), 117–138. https://doi.org/10.1111/j.1755-2567.2010.01092.x

Jespersen, B., & Carrara, M. (2013). A new logic of technical malfunction. *Studia Logica*, *101*(3), 547–581. https://doi.org/10.1007/s11225-012-9397-8

Juvshik, T. (2021a). Artifactualization without physical modification. *Res Philosophica*, *98*(4), 545–572. https://doi.org/10.11612/resphil.2092

Juvshik, T. (2021b). Function essentialism about artifacts. *Philosophical Studies*, *178*, 2943–2964. https://doi.org/10.1007/s11098-020-01594-w

Juvshik, T. (2025). What makes a kind an *artifact* kind? *Synthese*, *205*, 66. https://doi.org/10.1007/s11229-025-04914-x

Karray, M. H., Ameri, F., Hodkiewicz, M., & Louge, T. (2019). ROMAIN: Towards a BFO compliant reference ontology for industrial maintenance. *Applied Ontology*, *14*(2), 155–177. https://doi.org/10.3233/AO-190208

Kassel, G. (2010). A formal ontology of artefacts. *Applied Ontology*, *5*(3–4), 223–246. https://doi.org/10.3233/AO-2010-0078

Kassel, G. (2023). A plea for epistemic ontologies. *Applied Ontology*, *18*(4), 367–397. https://doi.org/10.3233/AO-230031

Keet, C. M. (2020). The computer program as a functional whole. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 216–230). IOS Press.

Khan, Z. C., & Keet, C. M. (2015). An empirically-based framework for ontology modularisation. *Applied Ontology*, *10*(3–4), 171–195. https://doi.org/10.3233/AO-150151

Kipfer, B. A. (2021). *Encyclopedic dictionary of archaeology*. Springer.

Kitamura, K., & Mizoguchi, R. (2010). Characterizing functions based on ontological models from an engineering point of view. In A. Galton & R. Mizoguchi (Eds.), *Proceedings of the 6th international conference on formal ontology in information systems (FOIS 2010), Toronto, Canada, May 11–14, 2010* (pp. 301–314). IOS Press.

Koslicki, K. (2008). *The structure of objects*. Oxford University Press.

Koslicki, K. (2018). *Form, matter and substance*. Oxford University Press.

Koslicki, K. (2023). Artifacts and the limits of agentive authority. In M. Garcia-Godinez (Ed.), *Thomasson on ontology* (pp. 209–241). Springer Verlag.

Koslicki, K., & Massin, O. (2025). Artifact-functions: A capacity-based approach. In M. J. García-Encinas & F. Martínez-Manrique (Eds.), *Special objects: Social, fictional, modal, and non-existent* (pp. 31–52). Springer.

Koslicki, K., & Massin, O. (in press). Artifact kinds, functions, and capacities. *American Philosophical Quarterly*.

Loebe, F., Burek, P., & Herre, H. (2022). GFO: The general formal ontology. *Applied Ontology*, *17*(1), 71–106. https://doi.org/10.3233/AO-220264

Lombardo, V., Karatas, T., Gulmini, M., Guidorzi, L., & Angelici, D. (2022). Transdisciplinary approach to archaeological investigations in a semantic web perspective. *Semantic Web*, *14*(2), 361–383. https://doi.org/10.3233/SW-223016

Loughmiller-Cardinal, J. A., & Cardinal, J. S. (2020). Use, purpose, and function — letting the artifacts speak. *Heritage*, *3*(3), 587–605. https://doi.org/10.3390/heritage3030034

Machamer, P., Darden, L., & Craver, C. F. (2000). Thinking about mechanisms. *Philosophy of Science*, *67*(1), 1–25. https://doi.org/10.1086/392759

Masolo, C., Borgo, S., Gangemi, A., Guarino, N., & Oltramari, A. (2003). Wonderweb deliverable D18—Ontology library (final). Laboratory for Applied Ontology, National Research Council, Institute of Cognitive Science and Technology. Available online at http://wonderweb.man.ac.uk/deliverables/D18.shtml. (Last accessed on April 3, 2026).

Masolo, C., & Sanfilippo, E. M. (2020). Technical artefact theories: A comparative study and a new empirical approach. *Review of Philosophy and Psychology*, *11*(4), 831–858. https://doi.org/10.1007/s13164-020-00475-9

Masolo, C., Sanfilippo, E. M., Bottazzi, E., Ferrario, R., Mosca, A., & Vilardo, M. M. (2025). An observational approach to representing interpretation. *Applied Ontology*, *20*(4), 381–403. https://doi.org/10.1177/15705838251391711

Masolo, C., Vieu, L., Ferrario, R., Borgo, S., & Porello, D. (2020). Pluralities, collectives, and composites. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 186–200). IOS Press.

McCann, H. (1975). Trying, paralysis, and volition. *Review of Metaphysics*, *28*(3), 423–442.

McKitrick, J. (2003). A case for extrinsic dispositions. *Australasian Journal of Philosophy*, *81*(2), 155–174. https://doi.org/10.1080/713659629

McKitrick, J. (2018). *Dispositional pluralism*. Oxford University Press.

McKitrick, J. (2024). The metaphysics of artificial dispositions. In W. A. Bauer & A. Marmodoro (Eds.), *Artificial dispositions: Investigating ethical and metaphysical issues* (pp. 37–58). Bloomsbury.

Miettinen, K. (2018). The ontology of systems. In K. B. Laskey & D. Wijesekera (Eds.), *Proceedings of the third international ontology for the intelligence community conference (OIC-2008), Fairfax, VA, USA, December 3–4, 2008. CEUR workshop proceedings* (Vol. 440, pp. 1–4).

Mikalonytė, E. S. (2023). Musical works are mind-independent artifacts. *Synthese*, *203*(1), 1–28. https://doi.org/10.1007/s11229-023-04402-0

Millikan, R. (1984). *Language, thought, and other biological categories*. MIT Press.

Millikan, R. (1989). In defense of proper functions. *Philosophy of Science*, *56*(2), 288–302. https://doi.org/10.1086/289488

Mizoguchi, R., & Borgo, S. (2021). The role of the systemic view in foundational ontologies. In E. M. Sanfilippo, O. Kutz, N. Troquard, T. Hahmann, C. Masolo, R. Hoehndorf, & R. Vita (Eds.), *Proceedings of the 7th joint ontology workshops (JOWO 2021), Bolzano, Italy, September 11–18, 2021. CEUR workshop proceedings* (Vol. 2969, pp. 1–11).

Mizoguchi, R., & Borgo, S. (2022). Towards an ontology of representation. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 12th international conference on formal ontology in information systems (FOIS 2021), Bozen-Bolzano, Italy, September 13–17, 2021* (pp. 48–63). IOS Press.

Mizoguchi, R., & Borgo, S. (2025). An ontology of representation. *Applied Ontology*, *20*(2), 137–152. https://doi.org/10.1177/15705838251337943

Mizoguchi, R., Kitamura, Y., & Borgo, S. (2016). A unifying definition for artifact and biological functions. *Applied Ontology*, *11*(2), 129–154. https://doi.org/10.3233/AO-160165

Moltmann, F. (2013). *Abstract objects and the semantics of natural language*. Oxford University Press.

Mumford, S., & Anjum, R. L. (2011). *Getting causes from powers*. Oxford University Press.

Neander, K. (1991). Functions as selected effects: The conceptual analyst's defense. *Philosophy of Science*, *58*(2), 168–184. https://doi.org/10.1086/289610

Neuhaus, F. (2026). Dispositions and roles of generically dependent entities. In J. Beverley, C. M. Keet, N. Lamba, P. Lambrix, & S. Tiwari (Eds.), *Proceedings of the 11th joint ontology workshops (JOWO 2025). Catania, Italy, September 8–9, 2025. CEUR workshop proceedings* (Vol. 4176, pp. 1–9).

Neuhaus, F., & Hasting, J. (2022). Ontology development is consensus creation, not (merely) representation. *Applied Ontology*, *17*(4), 495–513. https://doi.org/10.3233/AO-220273

Niccolucci, F., Sorin, H., & Doerr, M. (2015). The formal logical foundations of archaeological ontologies. In J. A. Barceló & I. Bogdanovic (Eds.), *Mathematics and archaeology* (pp. 86–99). CRC Press.

Nolan, D. (2015). Noncausal dispositions. *Noûs*, *49*(3), 425–439. https://doi.org/10.1111/nous.12096

Olivero, I. (2019). Function is not enough: An externalist defeat for artifactual and social kind terms. *Grazer Philosophische Studien*, *96*(1), 105–129. https://doi.org/10.1163/18756735-000061

O'Shaughnessy, B. (1980). *The will: A dual aspect theory (2 Vols.)*. Cambridge University Press.

Oswalt, W. H. (1973). *Habitat and technology: The evolution of hunting*. Holt, Rinehart, and Winston.

Oswalt, W. H. (1976). *An anthropological analysis of food-getting technology*. John Wiley & Sons.

Otte, J. N., Beverley, J., & Ruttenberg, A. (2022). BFO: Basic formal ontology. *Applied Ontology*, *7*(1), 17–43. https://doi.org/10.3233/AO-220262

Otte, J. N., Kiritsi, D., Ali, M. M., Yang, R., Zhang, B., Rudnicki, R., Rai, R., & Smith, B. (2019). An ontological approach to representing the product life cycle. *Applied Ontology*, *14*(2), 179–197. https://doi.org/10.3233/AO-190210

Passinsky, A. (2024). Artifacts, artworks, and social objects. In K. Koslicki & M. J. Raven (Eds.), *The routledge handbook of essence in philosophy* (pp. 261–275). Routledge.

Perez, G. D. J. (2020). On the essence and ontology of systems. *Open Science Journal*, *5*(3), 1–15. https://doi.org/10.23954/osj.v5i3.2510

Piñeros Glasscock, J. S., & Tenenbaum, S. (2023). Action. In E. N. Zalta & U. Nodelman (Eds.), *The stanford encyclopedia of philosophy (Spring 2023 Edition)*. Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/spr2023/entries/action/. (Last accessed on April 3, 2026).

Porello, D., Terkaj, W., Vieu, L., Sanfilippo, E. M., & Compagno, F. (2025). Approximating DOLCE in OWL: The DOLCEbasic and DOLCEnaryRel core modules. *Applied Ontology*, *20*(4), 298–329. https://doi.org/10.1177/15705838251401450

Preston, B. (2013). *A philosophy of material culture: Action, function, and mind*. Routledge.

Preston, B. (2022a). Artifact. In E. N. Zalta & U. Nodelman (Eds.), *The stanford encyclopedia of philosophy (Winter 2022 Edition)*. Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/win2022/entries/artifact/. (Last accessed on April 3, 2026).

Preston, B. (2022b). The artifact problem: A category and its vicissitudes. *Metaphysics*, *5*(1), 51–65. https://doi.org/10.5334/met.86

Prior, E. W., Pargetter, R., & Jackson, F. (1982). Three theses about dispositions. *American Philosophical Quarterly*, *19*(3), 251–257.

Rabenberg, M., Benson, C., Donato, F., He, Y., Huffman, A., Babcock, S., & Beverley, J. (2024). Grounding realizable entities. In W. D. Duncan & R. Hoehndorf (Eds.), *Proceedings of the 15th international conference on biological and biomedical ontology (ICBO 2024), Enschede, Netherlands, July 17–19, 2024. CEUR workshop proceedings* (Vol. 3939, pp. 1–13).

Raven, M. J. (2025). Dynamics of artefacts. *Mind*, *fzaf037*. https://doi.org/10.1093/mind/fzaf037

Reicher, M. E. (2022). The primacy of abstract artifacts. In P. McNamara, A. J. I. Jones, & M. A. Brown (Eds.), *Agency, norms, inquiry, and artifacts: Essays in honor of Risto Hilpinen, synthese library 454* (pp. 235–246). Springer.

Roberts, M. (2024). A dispositional account of technical functions. *Synthese*, *204*, 108. https://doi.org/10.1007/s11229-024-04756-z

Rodrigues, F. H. (2023). A theory for ontological modeling of events based on systems. [Ph. D. Thesis] Federal University of Rio Grande do Sul, Brazil. http://hdl.handle.net/10183/263999. (Last accessed on April 3, 2026).

Rodrigues, F. H., & Abel, M. (2019). What to consider about events: A survey on the ontology of occurrents. *Applied Ontology*, *14*(4), 343–378. https://doi.org/10.3233/AO-190217

Röhl, J. (2012). Mechanisms in biomedical ontology. *Journal of Biomedical Semantics*, *3*(suppl 2), S9. https://doi.org/10.1186/2041-1480-3-S2-S9

Röhl, J., & Jansen, L. (2011). Representing dispositions. *Journal of Biomedical Semantics*, *2*(suppl 4), S4. https://doi.org/10.1186/2041-1480-2-S4-S4

Röhl, J., & Jansen, L. (2014). Why functions are not special dispositions: An improved classification of realizables for top-level ontologies. *Journal of Biomedical Semantics*, *5*, 27. https://doi.org/10.1186/2041-1480-5-27

Sanfilippo, E. M. (2021). Ontologies for information entities: State of the art and open challenges. *Applied Ontology*, *16*(2), 111–135. https://doi.org/10.3233/AO-210246

Sanfilippo, E. M., Markhoff, B., & Pittet, P. (2020). Ontological analysis and modularization of CIDOC-CRM. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 107–121). IOS Press.

Sanfilippo, E. M., Masolo, C., Borgo, S., & Porello, D. (2016). Features and components in product models. In R. Ferrario & W. Kuhn (Eds.), *Proceedings of the 9th international conference on formal ontology in information systems (FOIS 2016), Annecy, France, July 6–9, 2016* (pp. 227–240). IOS Press.

Sanfilippo, E. M., Masolo, C., Bottazzi, E., & Ferrario, R. (2024). Interpreting texts and their characters. In C. Trojahn, D. Porello, & P. P. F. Barcelos (Eds.), *Proceedings of the 14th international conference on formal ontology in information systems (FOIS 2024), online, July 8–9 and Enschede, Netherlands, July 15–19, 2024* (pp. 119–133). IOS Press.

Scheuermann, R. H., Ceusters, W., & Smith, B. (2009). Toward an ontological treatment of disease and diagnosis. In *Proceedings of the 2009 AMIA summit on translational bioinformatics* (pp. 116–120). American Medical Informatics Association.

Schulz, S., & Jansen, L. (2018). Towards an ontology of religious and spiritual belief. In S. Borgo, P. Hitzler, & O. Kutz (Eds.), *Proceedings of the 10th international conference of formal ontology in information systems (FOIS 2018), Cape Town, South Africa, September 17–21, 2018* (pp. 253–260). IOS Press.

Searle, J. R. (1995). *The construction of social reality*. The Free Press.

Smith, B., Ameri, F., Cheong, H., Kiritsis, D., Sormaz, D., Will, C., & Otte, J. N. (2019). A first-order logic formalization of the industrial ontology foundry signature using basic formal ontology. In A. Barton, S. Seppälä, & D. Porello (Eds.), *Proceedings of the 5th joint ontology workshops (JOWO 2019), Graz, Austria, September 23–25, 2019. CEUR workshop proceedings* (Vol. 2518, pp. 1–12).

Smith, B., & Ceusters, W. (2010). Ontological realism: A methodology for coordinated evolution of scientific ontologies. *Applied Ontology*, *5*(3–4), 139–188. https://doi.org/10.3233/AO-2010-0079

Smith, B., Ceusters, W., Klagges, B., Köhler, J., Kumar, A., Lomax, J., Mungall, C., Neuhaus, F., Rector, A. L., & Rosse, C. (2005). Relations in biomedical ontologies. *Genome Biology*, *6*(5), R46. https://doi.org/10.1186/gb-2005-6-5-r46

Sowa, J. F. (2015). Signs and reality. *Applied Ontology*, *10*(3–4), 273–284. https://doi.org/10.3233/AO-150159

Spear, A. D., Ceusters, W., & Smith, B. (2016). Functions in basic formal ontology. *Applied Ontology*, *11*(2), 103–128. https://doi.org/10.3233/AO-160164

Sperber, D. (2007). Seedless grapes: Nature and culture. In E. Margolis & S. Laurence (Eds.), *Creations of the mind: Theories of artifacts and their representation* (pp. 124–137). Oxford University Press.

Stuchlik, J. (2013). From volitionalism to the dual aspect theory of action. *Philosophia*, *41*(3), 867–886. https://doi.org/10.1007/s11406-013-9414-9

Terrone, E. (2023). Taking abstract artifacts seriously—The functioning and malfunctioning of fictional characters. *Philosophies*, *8*(6), 105. https://doi.org/10.3390/philosophies8060105

Terrone, E. (2024). Are works of art affective artifacts? If not, what sort of artifacts are they? *Topoi*, *43*, 737–746. https://doi.org/10.1007/s11245-024-10045-8

The Common Core Ontologies (CCO) Repository. (2024, November 6). GitHub. https://github.com/CommonCoreOntology/CommonCoreOntologies. (Last accessed on April 3, 2026).

Thomasson, A. L. (1999). *Fiction and metaphysics*. Cambridge University Press.

Thomasson, A. L. (2004). The ontology of art. In P. Kivy (Ed.), *The Blackwell guide to aesthetics* (pp. 78–92). Blackwell.

Thomasson, A. L. (2006). Debate about the ontology of art: What are we doing here? *Philosophy Compass*, *1*(3), 245–255. https://doi.org/10.1111/j.1747-9991.2006.00021.x

Thomasson, A. L. (2014). Public artifacts, intentions, and norms. In M. Franssen, P. Kroes, T. A. C. Reydon, & P. E. Vermaas (Eds.), *Artefact kinds: Ontology and the human-made world* (pp. 45–62). Springer.

Toyoshima, F. (2020). Natural necessity: An introductory guide for ontologists. *Applied Ontology*, *15*(1), 61–89. https://doi.org/10.3233/AO-190219

Toyoshima, F. (2021). Roles and their three facets: A foundational perspective. *Applied Ontology*, *16*(2), 161–192. https://doi.org/10.3233/AO-210244

Toyoshima, F., & Barton, A. (2024a). Foundations for a realist ontology of mental representation. In F. Toyoshima, et al. (Ed.), *Proceedings of the 9th joint ontology workshops (JOWO 2023), Sherbrooke, Québec, Canada, July 19–20, 2023. CEUR workshop proceedings* (Vol. 3637, pp. 1–8).

Toyoshima, F., & Barton, A. (2024b). Two approaches to the identity of processes in BFO. In F. Toyoshima, et al. (Ed.), *Proceedings of the 9th joint ontology workshops (JOWO 2023), sherbrooke, Québec, Canada, July 19–20, 2023. CEUR workshop proceedings* (Vol. 3637, pp. 1–15).

Toyoshima, F., Barton, A., & Dooley, D. (2025). Two ontological approaches to food products. In T. P. Sales, C. Masolo, & C. E. Keet (Eds.), *Proceedings of the 15th international conference on formal ontology in information systems (FOIS 2025), online, September 4 and Catania, Italy, September 10–12, 2025* (pp. 225–239). IOS Press.

Toyoshima, F., Barton, A., & Ethier, J.-F. (2022a). Affordances and their ontological core. *Applied Ontology*, *17*(2), 285–320. https://doi.org/10.3233/AO-220267

Toyoshima, F., Barton, A., & Ethier, J.-F. (2022b). Investigating functions in BFO from the viewpoint of extrinsic dispositions. In T. P. Sales, et al. (Ed.), *Proceedings of the 8th joint ontology workshops (JOWO 2022), Jönköping, Sweden, August 15–19, 2022. CEUR workshop proceedings* (Vol. 3249, pp. 1–7).

Toyoshima, F., Barton, A., & Grenier, O. (2020). Foundations for an ontology of belief, desire and intention. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 11th international conference on formal ontology in information systems (FOIS 2020)* (pp. 140–154). IOS Press.

Toyoshima, F., Barton, A., Jansen, L., & Ethier, J.-F. (2022c). Towards a unified dispositional framework for realizable entities. In B. Brodaric & F. Neuhaus (Eds.), *Proceedings of the 12th international conference on formal ontology in information systems (FOIS 2021), Bozen-Bolzano, Italy, September 13–17, 2021* (pp. 64–78). IOS Press.

Toyoshima, F., Barton, A., & Koslicki, K. (2024b). Artifactual functions: A dual, realizable-based view. In Í Oliveira, P. P. F. Barcelos, R. Calhau, C. M. Fonseca, & G. Righetti (Eds.), *Proceedings of the 10th joint ontology workshops (JOWO 2024), Enschede, Netherlands, July 15–19, 2024. CEUR workshop proceedings* (Vol. 3882, pp. 1–14).

Toyoshima, F., Barton, A., Koslicki, K., & Massin, O. (2024a). The interconnection between artifacts and realizable entities. In Í Oliveira, P. P. F. Barcelos, R. Calhau, C. M. Fonseca, & G. Righetti (Eds.), *Proceedings of the 10th joint ontology workshops (JOWO 2024), Enschede, Netherlands, July 15–19, 2024. CEUR workshop proceedings* (Vol. 3882, pp. 1–14).

Toyoshima, F., & Delley, G. (2026). Towards a realism-based ontology of archeology: Artifacts, CIDOC-CRM and BFO. In J. Beverley, C. M. Keet, N. Lamba, P. Lambrix, & S. Tiwari (Eds.), *Proceedings of the 11th joint ontology workshops (JOWO 2025). Catania, Italy, September 8–9, 2025. CEUR workshop proceedings* (Vol. 4176, pp. 1–11).

Toyoshima, F., & Jansen, L. (2026). Malfunctioning artifacts: A step towards a realizable-centered unifying account. In J. Beverley, C. M. Keet, N. Lamba, P. Lambrix, & S. Tiwari (Eds.), *Proceedings of the 11th joint ontology workshops (JOWO 2025). Catania, Italy, September 8–9, 2025. CEUR workshop proceedings* (Vol. 4176, pp. 1–14).

Toyoshima, F., & Niki, S. (2021). Semantics matters: A new light on ontological commitments of logics. In E. M. Sanfilippo, O. Kutz, N. Troquard, T. Hahmann, C. Masolo, R. Hoehndorf, & R. Vita (Eds.), *Proceedings of the 7th joint ontology workshops (JOWO 2021), Bolzano, Italy, September 11–18, 2021. CEUR workshop proceedings* (Vol. 2969, pp. 1–16).

Toyoshima, F., & Niki, S. (2024). To be more concrete about abstracta and concreta. In C. Trojahn, D. Porello, & P. P. F. Barcelos (Eds.), *Proceedings of the 14th international conference on formal ontology in information systems (FOIS 2024), online, July 8–9 and Enschede, Netherlands, July 15–19, 2024* (pp. 74–88). IOS Press.

Troquard, N. (2014). A formal theory for conceptualizing artefacts and tool manipulations. In P. Garbacz & O. Kutz (Eds.), *Proceedings of the 8th international conference of formal ontology in information systems (FOIS 2014), Rio de Janerio, Brazil, September 22–25, 2014* (pp. 119–132). IOS Press.

Trypuz, R. (2007). Formal ontology of action: A unifying approach. PhD thesis, University of Trento, Italy. Available online at https://www.researchgate.net/publication/233990262. (Last accessed on April 3, 2026).

Tugby, M. (2024). The property of goal-directedness: Lessons from the dispositions debate. *Ratio*, *37*(4), 313–326. https://doi.org/10.1111/rati.12417

van Woudenberg, R., Ranalli, C., & Bracker, D. (2024). Authorship and ChatGPT: A conservative view. *Philosophy and Technology*, *37*, 34. https://doi.org/10.1007/s13347-024-00715-1

Vermaas, P. E., & Houkes, W. (2003). Ascribing functions to technical artifacts: A challenge to etiological accounts of function. *British Journal for the Philosophy of Science*, *54*(2), 268–289. https://doi.org/10.1093/bjps/54.2.261

Vetter, B. (2015). *Potentiality: From dispositions to modality*. Oxford University Press.

Vieu, L., Borgo, S., & Masolo, C. (2008). Artefacts and roles: Modelling strategies in a multiplicative ontology. In C. Eschenbach & M. Grüninger (Eds.), *Proceedings of the 5th international conference (FOIS 2008), Saarbrücken, Germany, October 31-November 3, 2008* (pp. 121–134). IOS Press.

Vignolo, M. (2010a). The ontology of products. *Metaphysica*, *11*(1), 1–16. https://doi.org/10.1007/s12133-009-0053-3

Vignolo, M. (2010b). Towards an ontology of products. In A. Galton & R. Mizoguchi (Eds.), *Proceedings of the 6th international conference on formal ontology in information systems (FOIS 2010), Toronto, Canada, May 11–14, 2010* (pp. 287–300). IOS Press.

Walter, L. (2013). Repeatable artworks as created types. *The British Journal of Aesthetics*, *53*(4), 461–477. https://doi.org/10.1093/aesthj/ayt026

Wang, X., Guarino, N., Guizzardi, G., & Mylopoulos, J. (2014). Towards an ontology of software: A requirements engineering perspective. In P. Garbacz & O. Kutz (Eds.), *Proceedings of the 8th international conference of formal ontology in information systems (FOIS 2014), Rio de Janerio, Brazil, September 22–25, 2014* (pp. 317–329). IOS Press.

Weigand, H., Johannesson, P., & Andersson, B. (2021). An artifact ontology for design science research. *Data & Knowledge Engineering*, *133*, 101878. https://doi.org/10.1016/j.datak.2021.101878

Williams, J. R. G. (2019a). *The metaphysics of representation*. Oxford University Press.

Williams, N. E. (2019b). *The powers metaphysic*. Oxford University Press.

Wouters, A. (2005). The function debate in philosophy. *Acta Biotheoretica*, *53*(2), 123–151. https://doi.org/10.1007/s10441-005-5353-6

Wright, L. (1973). Functions. *Philosophical Review*, *82*(2), 139–168. https://doi.org/10.2307/2183766

Xhignesse, M.-A. (2020). Failures of intention and failed-art. *Canadian Journal of Philosophy*, *50*(7), 905–917. https://doi.org/10.1017/can.2020.39

Yablo, S. (2014). *Aboutness*. Princeton University Press.

Yargan, D., & Jansen, L. (2024). Does biomimetics require a unified account of function? In Í Oliveira, P. P. F. Barcelos, R. Calhau, C. M. Fonseca, & G. Righetti (Eds.), *Proceedings of the 10th joint ontology workshops (JOWO 2024), Enschede, Netherlands, July 15–19, 2024. CEUR workshop proceedings* (Vol. 3882, pp. 1–14).