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Article

Information: A Conceptual Investigation

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Abstract: This paper is devoted to a study of the concept of information. We first situate the concept of information within the context of other philosophical concepts. However, an analysis of the concept of knowledge turns out to be the key when clarifying the concept of information. Our investigations produce the 'missing link' for the "severely neglected connection between theories of information and theories of knowledge" (Capurro/Hjørland). The results presented here clarify what information is and have the potential to provide answers to several of Floridi's "open problems in the philosophy of information".

Keywords: information; knowledge; certainty; semiotics; semantics; pragmatics

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1. Introduction

This paper is devoted to a study of the nature of information. Its intention is to contribute to an understanding of the *concept* 'information'. A conceptual specification is normally demanded by any question that begins "What *is* ...?": These kinds of questions are raised on a conceptual level and demand an answer of the same type. A conceptual analysis is therefore required to study the nature of information. Conceptual clarifications are one of the main concerns of philosophy, and this paper contributes to an understanding of the *concept* of information from a philosophical perspective.

In his most influential paper on open problems in the philosophy of information, Floridi notes that the question "What is information?" as considered so far "only demarcates a wide area of research; it does not map out its specific problems in detail" (*cf.* [1]; p. 556). Following Floridi's map metaphor, the goal of this paper is to present a system of 'landmarks' that map the conceptual landscape of the field of information. First, we need to inspect the entire landscape to judge which area will be

suitable for subsequent settlement. Then, to secure our intended property, we will erect fences to clearly separate the inner and outer boundaries of our appropriation. Next, to provide orientation within the field, we will develop a framework to explore its inner structures in greater detail. Our presentation should result in a panoramic tower to overview and situate other descriptions of the landscape from a distinguished position.

Before this can be done, however, we must evaluate the threats that our attempt to take land has exposed. We start by surveying aspects of information that have been examined in the literature. This survey should hint at an understanding of the concept of information and, at the same time, show the boundaries of what constitutes a conceptual analysis of information and what describes a restricted perspective that addresses specific circumstances.

2. What Information Is Not

To develop a conceptual understanding of information, we begin by analyzing what is beyond the borders we are surveying; in other words, we must examine what information *is not*. Throughout the history of this field, a number of concepts have been related to information in one form or another, and we will briefly review some of the most prominent ones. Because our aim, however, is to produce a conceptual clarification of what information *is*, the crucial goal of the subsequent considerations is to determine whether a conceptual understanding of information may evolve from the respective approaches.

To begin, we observe that a considerable body of work has associated information with uncertainty. Thus, an important question is whether a conceptual description of 'information' should adopt an aspect of uncertainty (or certainty). The first aspect we should consider is the relationship between these concepts.

2.1. Uncertainty

Beginning with the pioneering work of Shannon [2] and Shannon-Weaver [3], various aspects of uncertainty have been associated with information [4]. The most prominent aspects are certainly the channel capacity and entropy. Hintikka [5] later transferred the situation into a setting of propositions, thus reformulating the problem in the framework of logic. Because the semantic foundation of logic has been established through Tarski's conceptualization of truth, this approach is known as *semantic information*.

We agree that whatever information is, it reduces uncertainty; thus, uncertainty (as well as the concept of entropy) are undoubtedly related to information. Any conceptual clarification of information must ultimately explain the nature of this relationship if it is not directly grounded in uncertainty. The interesting question, however, is whether we can extract a conceptual specification of information from these types of treatments.

Now a conceptual clarification is not the primary concern of the given theories. This has been indicated by Shannon (see [2]; p. 379), who wrote:

> Frequently the messages have meaning; that is, they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem.

Thus, the specific focus of these approaches is explicitly not meant to contribute to a general clarification of the concept of information. In particular, it is not the intention of this approach to explain what information (in a general sense) might be. Shannon's theory defines a way to *measure* information, it does not explain *what it is*. But the latter point is exactly addressed when seeking for a characterization of the concept of information. As concepts must inherently be associated with meaning, no conceptual characterization can circumvent meaning. So if we don't have meaning at hand, it is not to be seen how a conceptual clarification may evolve. This excludes any approaches from our investigation that do not involve meaning.

On the other hand, we admit that uncertainty is closely related to the concept of information: we have agreed that it reduces uncertainty. So we may ask whether information can be grounded in uncertainty in a *conceptual* manner. The concept of information, however, is certainly not sufficiently explained (even if we adopt the pragmatic perspective; cf. the *pragmatic maxim* of Peirce mentioned below [6]) by characterizing its effect as a form of 'reduction' of 'uncertainty'. Such an approach does not illuminate the concept of information itself, but rather focuses on the effects of information for some given structure or configuration. We will show in the sequel what this exactly means.

So the aspect of uncertainty, considered in an isolated manner, seems to not be the key concept for a conceptual clarification of 'information'. Information may contribute to or result in the reduction of uncertainty, but it is not an issue of uncertainty itself. Thus the kind of relation between these concepts must be established on another basis. So let us then turn to approaches that are explicitly semantic ones.

2.2. Semantic Information and Information Flow

There are other conceptualizations of 'information' found in (the exact) science(s). The notion of semantic information has been brought up by the technical report of Bar-Hillel and Carnap [7], who build on ideas put forth by Popper [8–11]. It is inspired by Shannon's approach to information and attempts to weave the entropy approach into a logical setting. By doing so, semantic information theory inherits an understanding of information as something that reduces uncertainty. Because uncertainty is not the key concept in our discussion, semantic information will not contribute to a clarification of 'information'.

Hintikka's pioneering paper on semantic information [5] presents a theory of information as a logical interpretation of probability, as opposed to a statistical (or frequency-based) theory of probability that examines what happens in the long run in certain types of uncertainty. A logical interpretation focuses on the possibility of distinguishing alternatives by means of their formal expressions in the logical language.

Fred Dretske's work [12] motivated and initiated a series of further developments in 'semantic information theory'. The separation of information from its necessary interpretation allows us to study its usage, its properties as a pure carrier, and its functional behavior. This is the program Dretske [12] characterized as follows:

> Once this distinction [of information and meaning] is clearly understood, one is free to think about information (though not meaning) as an objective commodity, something whose generation, transmission, and reception do not require or in any way presuppose interpretive processes. One is therefore given a framework for understanding how meaning can evolve, how genuine cognitive systems [...] can develop out of lower-order, purely physical, information-processing mechanisms. [...] The raw material is information. (*cf.* [12]; p. vii)

In the sequel, we adopt Dretske's notion of a 'cognitive system', which, however, will be subject to further specifications.

Following this approach, Barwise and Perry [13] expanded its scope and presented a theory that proved to be influential. Their work was the starting point for Devlin's study of the concept of information [14]. Another approach was presented by Barwise and Seligman (s. [15]; p. 19) as an attempt to elaborate and improve on the theory of knowledge presented by Dretske. The crucial point is that a belief p should already carry the *information* that p. (In subsequent usage, we have chosen the notion 'conviction' instead of 'belief', for reasons that will be made clear.) The study of the functional phenomenon of information is the main task of the theory of information *flow*. (For an account of research in this field, see, for example, [16–18].)

This approach turns information into a fundamental concept on which knowledge may be based. It is thus the concept of 'knowledge' that is subject to clarification on the basis of information, rather than the other way around. Again, a conceptual clarification of information is not to be expected on this basis.

According to the semantic nature of logic after Tarski [19], a theory of information developed as a *logical* theory necessarily inherits its semantic status. This explains the denotation. Semantic information in this sense does not constitute an original understanding of information but rather suggests a treatment of the concept of information within a logical framework. In any case, a conceptual clarification should be performed in advance; it cannot be substituted by logic. Instead, structural properties of such a conception must be included in the model associated with the framework of logic. This means that a respective conceptualization must precede the logical treatment of the phenomenon. Thus, it is not to be seen how this approach may contribute to our investigation.

2.3. Perception and Epistemology

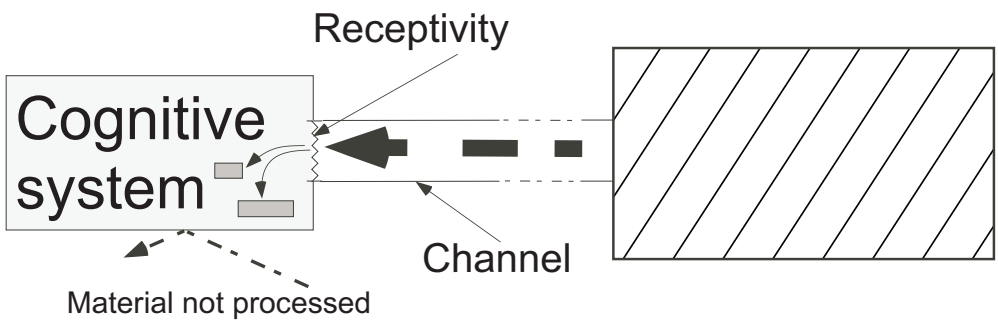
It is an inherently philosophical issue to explain the emergence of concepts, along with a subsequent synthesis of judgments, from sensory affections. However, it is rather psychology and (neuro-)physiology that address the first steps in the transition from sensory effect or stimuli (whatever is considered as giving rise to perception) to concepts. Perception denotes the initial part of the process leading to awareness of the world, which we can articulate in conceptual form. It is often conceived as being on the borderline between neurophysiology, psychology, and philosophy. For example, Kant, whose epistemology undoubtedly constitutes a decisive point in the development of philosophy, integrated the neurophysiological knowledge of his time into his theory of the constitution of knowledge by synthesis of perception. Acknowledging that the pre-conscious organization of sensory data is rather a matter of neurophysiology or psychology (*cf.* [20]; p. 15) led him to an interdisciplinary cooperation

with the physician Soemmering (see [21]; pp. XXIII, 397–414, XII, 30–36). Sense as a reliance on physical abilities is still subject to modern psychological studies (which include modeling aspects of how the human brain (pre-)processes sensory states as the initial step of a process resulting in conceptual knowledge; for a modern investigation of this subject, see [22]; for another theory of perception, *cf*. Dretske [23] and [24], for more details see the section below).

The most interesting aspect for this project, however, is the synthesis of sensory material to judgments relating concepts (see [25]). What triggers the further processing (*i.e.*, what affects the sensory aspects of the cognitive system) is only present through the consequences it activates within the cognitive system. It is the system's own contribution that ultimately remains: a conceptual orientation in 'the world'. In other words, an original cause is completely inaccessible and only present via the results of the processes it triggers.

Identifying information as that which affects receptivity would bind information to epistemological issues [26]. Information, in this sense, would be just another word for stimuli: we do not know what information *is*, except that it initiates processes that ultimately result in knowledge. Such a conceptualization requires information to pass through the entire epistemic process, including the first neurophysical and psychological steps, to end up as knowledge. But during this process, its original constitution vanishes and is no longer accessible. We would then again be in a situation in which we do not have access to what information *is*, but only to the results of a process in which information is in the initial position. Figure 1 illustrates this situation. The hatched area is completely hidden from our inspection or is a matter of the sciences only and does not allow a conceptual analysis.

Figure 1. Information and epistemology.



This approach does not seem to fit with our intuitive conception of information. Moreover, the situation would be essentially the same as with the interrelation between information and uncertainty discussed above. If we maintain that information is different from stimuli, the situation cannot be as presented in Figure 1.

Consequently, we emphasize the difference between information and that which causes (or gives rise to) perception. We must keep epistemology (in the sense of explanations of the *constitution* of knowledge) separate from investigations of the nature of information. (It should be noted that this reflects the modern understanding of 'information'. The situation up to the Middle Ages was different. For more details see the next section.)

Putting these aspects together, we note that information may be related to the *results* of epistemic processes, but it is not related to the processes necessary to *establish* knowledge. Handling information

may involve cognitive abilities such as reflection, interpretation and understanding, but these must be understood as mental activities that are different from epistemic processes, which focus on the constitution and production of knowledge.

2.4. Information Reviewed

In this section, we have shown that uncertainty is not a key issue for a *conceptual* understanding of information, although it is undoubtedly related to it. Conceptualizations of information that focus solely on aspects of uncertainty cannot capture the nature of the concept of information. This conclusion excludes many conceptualizations found in the literature from our investigation of the nature of information.

Similarly, studies of channel capacity offer an isolated view of this configuration, but they do not explain the essential aspect of information. For the purposes of this paper, channel capacity addresses a single phenomenon as part of a more complex setting in which the concept of information may be developed. These studies have produced highly interesting scientific results, but they do not contribute to an understanding of what information *is*, at least not directly.

In the following sections, we will present an understanding of information that does *not* incorporate aspects of uncertainty on a conceptual level. On the contrary, these deliberations will provide evidence that information should be tied to certainty (although it will not be characterized explicitly in terms of certainty). We have admitted that information and uncertainty are related, and we must now show how and under what circumstances our characterization implicitly involves an aspect of uncertainty. If we claim that our understanding of information is basic, we should be able to explain the aspect of uncertainty that has been established by the approaches considered in this section.

For the time being, we may indicate that the connection to uncertainty is to be understood not on the conceptual level but on some other level. This may be because a conceptual description of information could not be established via uncertainty. We will return to this point later in the paper.

As we considered the relationship between information and epistemology, we excluded from our analysis approaches that focus on specific aspects like the *effect* of information on some configuration, entity or (cognitive) system. Furthermore, the way we are confronted with information and who or what *produces* information are issues outside the scope of our discussion, although they may be related to aspects of information. Simply affecting something is too restricted an action to count as information. May we really say, for example, that we *get informed* about the world outside through our senses? Do we really speak of information as an act of individual considerations we perform as isolated entities? If the answer to these questions is *no* (and I think that is so), we have to conclude that epistemology is not able to clarify the concept of information. The conceptual nature of information and the conditions of its generation are simply different issues.

Setting aside approaches that concentrate on the effects of information and focusing on the development of a conceptual clarification, we must acknowledge that we need direct access to the *concept* of information in some way. This is because information cannot remain totally external to a cognitive system. We have to examine effects that we have shown to be inappropriate for an investigation of the conceptual clarification of information. The cognitive system under consideration must be in

contact with whatever 'information' finally turns out to be. Inside a cognitive system, however, we find conceptual conditions.

When all these arguments are combined, we see that in order to establish a conceptual characterization of information, we have to consider *conceptual* forms. All approaches neglecting the conceptual nature of information do not illuminate the concept of information itself; they merely consider conditions of its experience, its application, or the like. The next section of this paper examines concepts that relate to information on a conceptual level. This approach seems to be more promising for our intended purpose and will clarify the relationship of information to epistemology.

3. Information and Knowledge

Complementing our discussion by another perspective, we refer to the etymological kernel of the concept 'information'. The *word* 'information' has Latin roots ("informatio"). 'In-formare' means "to bring something into a shape, a form" (*cf.* [27]). The *Thesaurus Linguae Latinae* [28] gives detailed references to its uses in Latin since Vergil until the seventh century. Information is mostly seen as the "activity or process of endowing some material entity with form" like a sculptor who 'in-forms' a piece of marble into a statue. The prefix 'in' strengthens the act of giving a form to something.

It should be noted, though, that the *concept* of information dates back at least to Platon and Aristotle. Even a simplistic outline of the associated philosophical positions, however, would be outside the scope of this work. Instead, we concentrate on some facets that are related to our discussion here.

Several Greek words were translated with *informatio* or *informo* such as *hypotyposis* (in a rather moral context) and *prolepsis* ("representation"; this is the word Cicero used to stand for Epicure's usage), but the ones that are central to the ontological and epistemic conceptualizations of Platon and Aristotle, respectively, are *eidos/idea, morphe, typos*, and also *hyle* (matter). *Eidos* and *idea* rather bear an ontological sense, whereas *typos* (especially in Platon's epistemology) may vary and relate to ontological as well as to epistemic issues. *Morphe* is primarily Aristotelian; it seldom occurs in Platon's work (*cf.* Capurro's work [29]; p. 19). It is a principle of being and is used to stand for 'outer form' (see [29]; p. 23).

The relationship to the Greek is quite obvious for Cicero and Augustine. Moreover, Capurro and Hjørland [30] argue that these concepts also have their roots in every-day-use of these words "particularly in the primitive context of pottery as well as in the Greek experience of limitation and shining-forth of what we perceive sensually (*phainonemon*)" (*cf.* [30]; p. 352).

But Cicero also used this word in a rhetorical context

> [...] to describe the active and a posteriori action of the mind depicting something unknown or helping memory, as part of the ars memoriae, to better remember a past situation through the pictorial representation of a sentence (sententiae informatio). (*cf.* [30]; p. 352)

Augustine is influenced by the Greek ontology and epistemology as well as the Christian tradition. He calls the process of visual perception *informatio sensus*. Representations of perceived objects are stored in memory. These images do not inform the soul or the rational intellect (*intelligentia rationalis*), but only reflection (*cogitatio*), *i.e.*, the capability dealing with internal representations (*informatio cogitationis*), does.

Throughout the Middle Ages Capurro sees that 'information' is "...commonly used in the aforementioned epistemological, ontological, and pedagogical contexts by several authors" (*cf.* [30]; p. 353) the most prominent one being Thomas Aquinas (see [29] for more details).

According to Thomas Aquinas' interpretation of the Aristotelian *eidos* or *morphe*, and *hyle*, both principles cause the unity of an individual being (*informatio materiae*): "the action of 'informing' with some active or essential quality" ([31]; see also [29]; pp. 122ff).

Most important he identifies an ontological difference between *informatio* and *creatio*. Because of the unity of the human body with the soul as substantial form (*forma substantialis*) Thomas emphasizes the unity of the knowledge process seen as a double process (*informatio sensus* and *informatio intellectus possibilis*) of abstracting the forms (*forma, species*; the Aristotelian *eidos* or *morphe*) of things and of going back to the things in a process of sensory-bounded intellectual re-cognition ("conversio ad phantasmata"). In this process of (re-)cognition the active intellect (*intellectus agens*) plays a special role (for a more detailed exposition see [29,30]).

Whereas an epistemological and ontological notion of information was the key concept throughout the Middle Ages, the decisive context shift leading to the modern understanding is related to Descartes work. Abandoning the "direct perception" of the scholastics (*cf.* Capurro [29]), Descartes introduced the "res cogitans" as the instance to reflect. It was his conception that initiated a transition from the medieval ontological concept to an understanding as 'communicating something to someone'. From this time on "the context of this in-forming shifted from matter to mind" (Peters [32]; p. 12). However, concerning the further development of the concept, Capurro and Hjørland note that the *concept* of information "ceases to be a higher-level concept until the rise of information theory in the 20th century" (*cf.* [30]; p. 354). For example, Kant's deduction of pure concepts may well be seen as a theory of 'forms' (the categories) under which material is to be subsumed to establish knowledge (see [25]).

Hence 'in-formation' remains a shaping process. While 'in-formare' means to bring *some material* (the counterpart of the concept 'form') into another form or shape, the material remains the same. To bring something into a form does not change what is brought into this new shape: in-formation is not in-materialization! The material remains the same, but the way it is presented changes: the same material appears in a new shape. Accordingly, information is something that emerges from and represents an (intellectual) action on the underlying material, namely its formation. From this analysis, we may deduce again that epistemology and information are not tied to each other from a conceptual point of view.

This approach does not address the questions of who performs this shaping or what is in-formed. From a logical point of view, the description of 'information' is a statement containing two existential quantifiers. It expresses that someone has performed the act of bringing something into shape. Considered this way, the characterization of information indicates that it is the *result* that is of primary interest without neglecting the basis of this action, the (given) material. Information is confrontation with the result but not necessarily with its genesis—the genesis may attract some interest on its own, but this is a separate issue that will be addressed later. However, information cannot be understood without the material on which something is performed; it cannot be separated from material. The material must be present to constitute the ground on which this shaping can be performed. Forming involves forming something. Form and material are interrelated. So in-formation is associated with what is exposed to this forming. The material is needed to carry the form it receives. Thus, we finally have two 'somethings'

that are necessarily connected to the concept of information from the perspective of its etymology: the one who performs the forming and the (some)thing that is formed.

A second aspect is important for our investigation as well. Information is not self-referential; you cannot inform yourself. Information implicitly hints at some external excitation, and it requires something outside of a cognitive system. Nevertheless, it must be accessible for further inspection, though not in the form of an input that initiates an epistemic process. This means that the emphasis is *not* on the constitution of knowledge. Information is not primarily something that is *produced* by a cognitive system (we will see that *handling* information must reflect on the conditions of its constitution, but this is a separate point). The production process is not the focus when speaking of information in general, which would make information indistinguishable from knowledge, but is its result. Thus, Figure 1 fails to represent the setting in which information occurs. Instead, it rather abandons the concept of information. Hence, we must find another figure to more adequately represent the setting in which we speak of information.

Because information is not self-referential, it must be established and (pre-)processed outside of the cognitive system under consideration. However, information cannot be outside of and inaccessible to a cognitive system. We have seen that the aspect of affecting or getting in touch with something is too restricted to count as information. This makes some process of acquisition inevitable, and this process cannot primarily be understood in an epistemological sense. The whole situation must then be interpreted as an interchange between two cognitive systems; in other words, this process is an act of communication.

If we reduce cognitive systems to pure configurations, we would still not be able to capture a conceptual understanding of information. Mere changes in an interior configuration caused by some form of input do not qualify as information. There must be more. Does a computer get informed by my typesetting? I don't think so, although it certainly changes its internal configuration. One thing that distinguishes mere configurations from cognitive systems is awareness (which includes abilities like reasoning). This involves an aspect of reflection, or at least of the act of 'in-forming', which is associated with information. So information relies on a form of interpretation that, in turn, must be based on *conceptual* structures. Merely reactive systems, such as thermometers, are unable to adopt the results of other thermometers unless they are connected via other reactive systems. However, processing external results cannot be more than just triggering the system's functionality[33]. The whole must be seen as one system that is not understood as 'external' as suggested by the above reflection on 'information'. So the interchange must be based on *conceptual* structures.

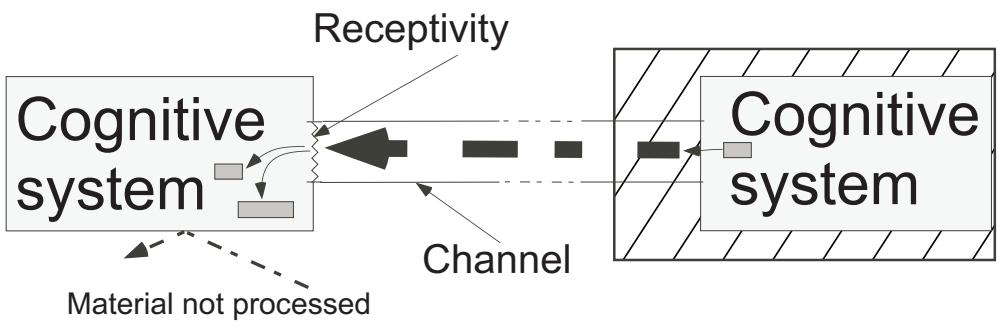
This line of inquiry relates to another meaning of 'information' that may be identified in the historical development of the concept, namely 'instruction' (see again [27]; for a more complete survey of uses in the biological, pedagogical or moral context see Capurro and Hjørland [30]). As such, information must be understandable and 'processable'—not in the form of modification or transformation, but rather as an appropriation. This again indicates that it must be available in conceptual form.

We therefore need conceptual structures within the cognitive systems. Instead of speaking of receptivity or sensory perception, we must consider this appropriation to be an exchange of conceptual entities, *i.e.*, a communication phenomenon. This exchange seems to play an essential role in the context of information and must also be considered. Information cannot be characterized by

focusing on the receptive part of the model only. Instead, the model of an information setting must necessarily be symmetrical; as Brookes has said, at "both ends of the channel cognitive processes occur" (*cf.* [34]; p. 195). Concentrating on the receptive part only and ignoring what (if anything) we may find in the hatched part on the right-hand side in Figure 1 would not reflect a difference in epistemic processes. Instead, it neglects the symmetry of the setting in which information may occur and only considers the passive, receptive part of 'something flowing' (whatever is considered to be 'outside'). Specifically, this approach does not produce or contribute to a conceptual analysis.

Thus, the basic setting in which information occurs must admit a look into the hatched area and explore its inner structures. We must understand what we may find there, and, most importantly, we must be able to develop a *conceptual* understanding. As we have seen, developing a conceptual understanding involves a second cognitive system along with a communication setting. Figure 2 therefore illustrates the situation needed to achieve a conceptual clarification of information.

Figure 2. The context of information



The most prominent candidate of a conceptual nature in this context is knowledge. Information appears in situations in which knowledge is also involved, and there is a close connection between information and knowledge. This connection, however, does not illuminate the *concept* of information. It connects concepts and clarifies their relationships, but not their internal constitutions. Hence we must pursue the kind of relationship between knowledge and information.

As we will see, this relationship has an effect on what is called the 'channel' in Figure 2. Handling information is clearly different from experiencing 'the world'. Another consequence of the distinction between knowledge and Information, therefore, concerns the nature of the exchange between the two cognitive systems. The question arises of what is exchanged—or, in other words, what is the material that is 'in-formed'. It is common understanding that this material is denoted as 'data'. Its relationship to knowledge and information has been hinted at in various interpretations in the field of information science. In the next step, we survey characterizations in this area to identify aspects that may give rise to a conceptual characterization of 'information'. An excursion into philosophy will further illuminate and reshape our problem.

4. Conceptualizations of Information

Even a short consideration of possible meanings of the term 'information' immediately reveals that very different and widespread understandings of the concept of information have evolved. "There is no

accepted science of information", begin Barwise and Seligman in the preface to their monograph [15], and there is certainly no broadly accepted characterization of information.

An indispensable first step towards a theory of information is to clarify the concept of information at its different levels. Accordingly, we start with a survey of conceptualizations of 'information', discuss its essential aspects and, finally, systematize insights about the nature of information that appear in the literature. This review is not meant as a comprehensive study of the concept of information in different contexts; such an attempt would certainly deserve a more detailed analysis (for a more detailed exposition of the concept of information in the context of information and library sciences and information retrieval, consult [35]). Instead, we trace understandings and usages of the terms to determine the constitutive properties that must be included in a prospective theory of information. This theory must be developed in conformity with the (underlying principles of the) common usage of the concept.

This chapter is therefore intended to be an orientation to the landscape of understandings of 'information', establishing landmarks and identifying points of view. A coherent interpretation of all these isolated considerations in terms of a fundamental philosophical theory is a prerequisite to a well-founded characterization of the concept of information.

This section examines key concepts related to 'information' that should be taken into account for a conceptual characterization of information.

4.1. Concepts Associated with Information

The concept of 'information' has been closely tied to the concepts of 'knowledge' and 'data'. This connection appears to be a shared understanding in all contexts that address conceptualizations of 'information', and it is reflected in nearly all publications on the topic. The idea that information is tied to data is apparent in early publications that focus on the relationship between and mutual influences and perspectives on computer science and society. An early definition that is typical of understandings of this relationship was given in 1973 when Sanders (*cf.* [36]; p. 6) summarized an allegedly general understanding:

> *Information* is generally considered to designate data arranged in ordered and useful form. Thus, information will usually be thought of as relevant knowledge, produced as output of processing operations, and acquired to provide insight in order to (1) achieve specific purposes or (2) enhance understanding.

In this definition, information is understood to be the result of a transformative process that relies on a general understanding of terms like *useful*, *purpose*, and *understanding*. Interestingly, information is then further described as the result of a process that "reduces uncertainty" (*cf.* [36]; p. 6). This additional remark hints at understandings of 'information' that have been suggested by Shannon and others; as discussed above, these understandings attempt to turn the definition into a formally treatable form but result in a neglected *conceptual* reduction.

The connection between 'information' and 'data' is generally acknowledged. Evidence for this acknowledgement is provided by the joint ACM and IEEE *Computing Curricula 2001 Computer Science* [37] (see also the 2005 overview [38] of the different kinds of programs for which curriculum standards are available). The *Computing Curricula* demands a clarification of these concepts. The

ability to "compare and contrast information with data and knowledge" is explicitly noted as a learning objective in IT courses (*cf.* [37]; p. 134). However, precise definitions of the concepts are not given in the curricula, which are intended to constitute lists of indispensable topics. So this remarks provides us with a guideline for the central concepts that must be clarified for a formal theory of information. First, however, we consider other concepts that may be intimately connected with the concept of 'information'.

'Data', 'knowledge' and 'information' do not constitute an exhaustive list of related fundamental concepts. Two potential additions to this list include *wisdom* and *practice*.

4.1.1. Practice

To provide a framework for the ACT and IEEE *Computing Curricula 2001 Computer Science*, Denning [39] tries to define 'data', 'knowledge' and 'information' from the viewpoint of information technology education curricula for IT professionals. Denning says:

> "Information" is the judgment [...] that given data resolve questions. In other words, information is the meaning someone assigns to data. Information thus exists in the eyes of the beholder. (*cf.* [39]; p. 20)

In the course of his exposition, Denning explicitly extends the triad of 'data', 'knowledge' and 'information' by adding a fourth dimension, 'practice', that denotes "embodied knowledge". This dimension describes patterns of action that accomplish certain objectives with little or no thought (*cf.* [39]; p. 20). It should be noted that this fourth dimension does not seem to be of comparable epistemic status. Instead, it captures some abilities of the human mind to disburden attention from well-established actions (see [40]; *cf.* esp. volume 3.1, p. 35).

4.1.2. Wisdom

Another concept related to information is discussed in Ackoff's influential approach [41], in which the relationship between data, knowledge, and information is understood to involve a conceptual transition from data to knowledge and from knowledge to information. This transition is initiated by an increased understanding and involves an additional step from knowledge to wisdom. Understanding relationships leads from data to information; understanding patterns results in knowledge; and understanding principles gives rise to wisdom.

In this approach, the concept of information is prior to the concept of knowledge: knowledge is created out of information, while in Sanders's approach [36], information was characterized via knowledge.

It appears that a closer interrelationship between data, knowledge, and information is fundamental. At the same time, *epistemic* dependence among concepts like practice or wisdom, on one hand, and data, knowledge, and information, on the other hand, remains at least doubtful. Beyond the mere conviction that data, knowledge, and information are closely related, there is no commonly shared understanding of the *kind* of relationship they share. It is our intention to contribute to this discussion as well.

4.2. Conceptualizations of Information in Organizational Units

Nonaka [42] provides an excellent summary of both Western and Japanese interpretations of knowledge in the context of business organizations, including an extensive bibliography of the literature to the mid-1990s. For another account of the usage of this concept, see also Robert Dunham's column [43] in the first issue of KM Briefs and KM Metazine, where he introduces an understanding of 'knowledge' as it is used in business organizations. In this context, knowledge is essentially *dynamic* and may be characterized as "knowledge as action" (see [42]; pp. 57f and [44]) according to the theory of cognition in Maturana [45]. This view of knowledge is characteristic of Ackoff's approach, in which knowledge is considered an *application* of data and information. We also find a widespread understanding of Denning's [39] approach to information in the business community: "information is data with meaning" (see also [46] and [47]).

Nonaka and Takeuchi emphasize the difference between *explicit knowledge*, which can be articulated in formal language and transmitted among individuals, and *tacit knowledge*, which is understood as personal knowledge embedded in individual experience and involving such intangible factors as personal belief, perspective, and values. This distinction was originally made by Michael Polanyi in 1966 (*cf.* [42]; pp. viii and p. 59) and has subsequently become very influential. Nonaka and Takeuchi stress that "the interaction between these two forms of knowledge is the key dynamic of knowledge creation in the business administration" (*cf.* [42]; p. ix).

The problem associated with the term *tacit knowledge* is not primarily its status as knowledge, but the interest an interpreter (an organizational unit) has in its preservation or accumulation (or simply in its usage). This analysis, however, is focused on an interpreter's interest in knowledge, or on the problem of acquiring knowledge. The focus of this approach is *not* on a conceptual analysis of knowledge (or information) but rather on an aspect of its usability or availability for an entity; in light of the philosophical background presented in the next section, it turns out that this intention is not an issue of the conceptualization of 'information'.

It is thus the challenge of an organizational enterprise to acquire, to record, and to transform tacit knowledge into a suitable form so that it can subsequently be turned into a valuable resource and utilized for business purposes and not only remain an individual proficiency.

Nonaka and Takeuchi summarize their study of the usage of information and knowledge in organizational structures and consider

> ...knowledge as a dynamic human process of justifying personal belief toward the 'truth'. (*cf.* [42]; p. 58)

This viewpoint is often understood in business as 'knowledge management'. It sees knowledge as a valuable but often unarticulated, and thus unexploited, source. This view especially emphasizes the dynamic process of knowledge *compilation* as a central challenge facing organizational units.

Although these theorists share a common view, these concepts mostly appear to be ad hoc definitions that lack a profound foundation. This argument was made in Stenmark's survey [48]:

> Not only are the *definitions* of the three entities vague and imprecise; the relationships between them are not sufficiently covered.

Data, knowledge, and information are often placed in a hierarchy, with data at the bottom, followed by information, and finally knowledge at the top (see [48]; p. 3). Stenmark continues:

> This image holds two tacit assumptions; firstly, it implies that the relationship is asymmetrical, suggesting that data may be transformed into information, which, in turn, may be transformed into knowledge. However, it does not seem to be possible to go the other way.

Murray [49] draws attention to the close relationship between *knowledge* and *abstraction*, the latter being understood in contrast to *detail*.

> One of the most important characteristics of knowledge is **abstraction**, the suppression of detail until it is needed [...]. Knowledge is **minimization** of information gathering and reading – not increased access to information. Effective knowledge helps you eliminate or avoid what you **don't** want. Such abstraction also enables you to make judgments in a variety of situations, to generalize.

This type of consideration led to the notion of *information economics* [50], which is concerned with the study of the tangible value of information holdings to business enterprises exhibited by *information mining*.

It is worth mentioning that 'knowledge' in this field is considered a *process* that constitutes a challenge and demands a task. It thus behaves dynamically. The challenge is to exploit all (tacit) knowledge acquired by members of an organizational unit to the benefit of the organizational unit itself. The task is the compilation of (individual) knowledge into a suitable generic form such that it can be utilized as a valuable resource. This compilation into a generic form may require some adjustment, which is considered abstraction. This abstraction may consist of a weak form, as in Wiig [51], who defined information as "facts organised to describe a situation or condition".

These views share a common understanding, which may be characterized as follows: members of organizational units generally accumulate valuable personal experience or beliefs ("tacit knowledge") that are not entirely subjective and yet not fully objective ([52]). This constitutes a valuable source for the overall interest of the organizational unit, so it is a challenge for the unit to "leverage the tacit knowledge of its members" (*cf.* [48]; p. 8) and to transform this individuated form of organizational knowledge—which is only present in distributed form and only available to individuals—into organizational knowledge (*i.e.*, "explicit knowledge"). It is only the explicit form of knowledge that can be systematically exploited on the organizational level and that can be viewed as a secured valuable possession. It is uniformly accessible to each member of the unit and allows specific processing (*i.e.*, "knowledge management") beyond individual awareness.

It is therefore a challenge for every organizational unit

- to access individual experience ("tacit knowledge")
- to collect it in a form available for the unit ("knowledge management")
- to extract the valuable core of this knowledge ("abstraction")
- to verify its contents ("true facts")
- to represent these in a form that can be utilized ("explicit Knowledge").

These conceptualizations of 'data', 'knowledge' and 'information' reflect the overall aim of an organization's interest. Emphasis is mostly on the *generation* and *aggregation* of knowledge by focusing on the *process* of abstraction, in which the *result* is (in light of the previous section) necessarily associated with 'knowledge'. This is in contrast to epistemic interests, in which the emphasis is not on the problem of the generation and aggregation of knowledge but on knowledge as the disposable conceptual basis for personal orientation and interpersonal communication about aspects of the world.

It should be mentioned, though, that there are also understandings in the field of organizational units that do not really conform to this view. Choo, in "The Knowing Organization" (*cf.* [53]; p. 62), for example, suggests an understanding of information as a change in the individual's state of knowledge and a capacity to act. This is a view that fits into an understanding in the context of epistemological studies.

A radically different view has been suggested by Tuomi [54,55], who proposes that data emerges as a result of adding value to information, which is knowledge that has been structured and verbalized (see also [48] on this topic). Consequently, there is no "raw" data. This is in accordance with the goal of an organizational unit to *store* the tacit knowledge for better use.

4.3. Conceptualizations of Information in Information Science

Different understandings of 'knowledge' and 'information' emerge from the approaches of information science, information technology, and business. In the 1980s, the information science community had a widespread debate about the fundamental concepts that constitute the field and the conceptual ground for its self-understanding. At that time, a discussion on foundational issues resulted in a detailed and carefully performed analysis of the previously unspecified concepts. As in the previous section, we again review some characterizations that have contributed to an overall understanding of the concept and that appear to be fundamental for our intentions.

Beyond a mere compilation of more or less unrelated aspects, this review will systematize the diverse aspects of the concept of information. In this sense, the different aspects are all meant to contribute to a faceted view of a whole.

4.3.1. Information as Difference

The most abstract specification of the concept of information may be found in Bateson [56] (*cf.* also [57]; p. 428 for some earlier considerations). According to Bateson,

$$\text{Information is [...] a difference that makes a difference.} \tag{1}$$

Although this fundamental characterization seems to provide the very core of a *conceptualization* of 'information', Bateson subsequently investigates possibilities for a universal definition and looks for a physical foundation for a theory of information. This paper does not follow Bateson's overall assumption. It does, however, assert that Bateson has identified the most abstract and general *description* of what 'information' is.

The task then is to re-interpret this characterization in a suitable setting. In particular, this interpretation must specify how differences occur, how "differences" may be recognized as such for a person or a system, and, especially, what their content is, *i.e.*, what is transmitted and what is its effect. In other words, the *nature* of a "difference" has to be clarified to make it an object of a theory of information.

4.3.2. Information as a Process

Losee [58] tried to unify different approaches to conceptualizations of information and proposed a "domain-independent" view of information that explicitly included areas as diverse as physics and models of human behavior. The unifying principle upon which his theory is based is an assumption about the *origin* of information. Losee claims that the fundamental phenomenon of information that supports most understandings of information depends on an underlying process (see [58]; p. 258). This is expressed in Losee's fundamental principle, "All processes produce information."

Information must then be viewed as the result of a generative process: "The values within the outcome of any process." This makes information a dependent concept, and *process* becomes the primary concept to be studied for a general characterization of information. Accordingly, the focus is shifted from information itself to the conditions of its generation: the ability to "produce an effect" (*cf.* [58]; p. 259).

One might be tempted to relate this notion of process to the essential relationship of possible actions highlighted in Peirce's philosophy of pragmatism (see [59]). But this line of thought is not pursued, and Losee looks for some other justification. From a systematic point of view, this approach poses several problems. It relates information to an understanding of 'process', emphasizing the detectable results of 'value' and 'outcome'. Moreover, as long as these concepts are not proven to be more basic than 'information', the definition remains incomplete and results in an unnecessary inflation of basic concepts. These concepts are not obviously 'prior' from a systematic point of view.

Losee is aware of this. Focusing on the etymological roots of 'information', Losee points to the substring 'in-form-'. This should provide a justification for the intended specification of "outcome" as "characteristics in the output" (see [58]; p. 256). Losee argues that:

$$\text{Information is } [\ldots] \text{ the values of characteristics in the processes' output.} \tag{2}$$

This formulation, however, just extends the list of unspecified terms that have to be clarified to include "characteristics" and "output." Losee promotes his approach by presenting the prototypical models for such processes, namely mathematical functions and causal mechanisms in physics. Two remarks should be made.

First, these notions and the dependencies established in the definition (2) hint at a technical treatment of 'process' and, consequently, the concept of 'information' as well. In this context, 'value' undergoes a

technical interpretation as a "variable returned by a function or produced by a process." This approach differentiates between processes and functions and understands the latter to be a subspecies of processes in a technical environment (see [58]; p. 267).

Second, this definition 2 seems to neglect the fact that at "both ends of the channel cognitive processes occur" (*cf.* [34]; p. 195). This second limitation has been observed by Losee as well. To overcome this restriction (which would essentially negate his attempt to establish a discipline-independent definition of information), he tries to extend his procedural characterization of information to cognitive and communication processes as well. According to his approach, this amounts to interpreting the "characteristics" of a given field. The conceptualization of "process" outside of technical areas including mathematics, however, remains altogether vague and is inspired mainly by his prototype models and enriched by epistemic considerations. It is sketched like 'knowledge' may be interpreted as the *results* of processes by corresponding processing abilities of the mind (*cf.* [58]; pp. 265ff). This may be viewed as an attempt to demonstrate how domain-specific extensions like 'meaning' may be integrated into his approach to demonstrate its universality.

In general, Losee's analysis lacks an adequate account of the cognitive processes beyond a study of perception and its interpretation, which is seen as a signal processing cognitive ability. On the contrary, understanding issues of a conceptual approach such as "usefulness" is considered a *limitation* of a generic definition because it restricts the "domain of discussions [...] to cognitive processes" (*cf.* [58]; p. 257). Thus, this approach precludes a generic definition with universal applicability. Losee demands that domain-specific definitions be set up in accordance with his definition as concretizations of his general description (*cf.* [58]; p. 257).

However, there are factors that make Losee's considerations important for our objective. In light of Bateson's abstract specification ("a difference that makes a difference"), Losee's definition of 'information' as inherently the result of a process may be interpreted as specifying what actually "makes" a difference: it is caused by an underlying process and, we may add, driven by purpose and interest! In this sense, Losee's principle may be re-interpreted as concretizing one facet of Bateson's abstract statement. This is the main aspect of Losee's approach that interests us.

4.3.3. Information as Transformation

The following statement from Belkin and Robertson's influential study [60] provides a further specification of Bateson's statement (1). It contains a partial answer to the question of *on what* information makes a difference and thus contributes to a more detailed understanding of the concept of information.

Information is that which is capable of transforming structure. (3)

According to a remark by Silvio Ceccato, the concept of "structure" in statement (3) is to be understood as a universal category in the philosophical understanding of the concept (*cf.* [60]; p. 198). However, this meaning may not have been the original intention of the authors; they commented that the philosophical status of the concept of "structure" would not affect the argument. As we will see, this is absolutely right. This comment may be viewed as an expression of the authors' suspicion that a systematization of this concept may be possible and even desirable. We suspect that the contextualization

of structure as a philosophical term has prevented the concept of information from being studied in a formalized system where "structure" has a concrete technical specification. Thus, the remark might be somewhat misleading in view of its consequences.

4.3.4. Modification of Knowledge Structures

An intrinsic description is provided by Brookes (*cf.* [34]; p. 197), who focuses on the nature of the transformation and the kind of structure that is altered:

$$\text{Information is that which modifies [...] a knowledge structure.} \tag{4}$$

The abstract definition (3) of "information" as "a difference that makes a difference" has been concretized. Given a 'structure' (and, we may add: which is represented in a suitable form), information is something external to this structure ("a difference") that may affect or change the internal disposition of this structure ("makes a difference") in a procedural sense. From this point of view, three phenomena remain to be considered:

- The internal constitution of the structure.
- The nature or 'carriers' of the external influences that "make a difference."
- The alteration of the structure after an effect by external influences.

4.3.5. Information and Knowledge

We have observed that information and knowledge *structures* are closely tied to one another. Moreover, *information* is defined as an alteration of a knowledge structure, which makes *knowledge* prior to *information* from a systematic point of view. The definition of *knowledge* and *information* put forth by Brookes (*cf.* [61]; p. 131) acknowledges this fact and focuses on the dependency between these concepts.

$$\textit{Knowledge} \text{ is a linked structure of concepts.} \tag{5}$$

$$\textit{Information} \text{ is a small part of such a structure.} \tag{6}$$

4.3.6. Information and Data

Another definition is based on a classic article by Richard Mason that relates information and data, which, according to the philosophical commitment, are given as *signs* ([62]; see also section 5.2):

$$\text{Information can be viewed as a collection of symbols [...]} \tag{7}$$

with the necessary addition, "which has the potential to alter the cognitive state of a decision maker." This definition emphasizes the question of what *carries* information, complementing Losee's process-oriented approach. At the same time, it hints at specific settings needed to turn data into information. Pure data viewed as (syntactically) organized signs are only considered information in a suitable context, *i.e.*, when endowed with an interpretation providing meaning.

4.3.7. Information and Meaning

The boundedness of information to interpretations (thus constituting meaning) is expressed as follows:

> Something only *becomes* information when it is assigned a significance, interpreted as a sign, by some cognitive agent. (*cf.* [12]; p. vii)

It should be noted, though, that this view of the concept of information is criticized by Dretske [12] as connecting information with meaning in a misleading way.

This definition relates 'information' to a state where "possible actions" are most desirable ("is assigned a significance"). In light of the philosophical background of this paper, the explicit relation to a decision maker (rightly) links the concept of 'information' to a "pragmatic situation". Moreover, the definition expresses that *signs* (symbols) are the carriers of information. However, the notion of an agent seems to be too restrictive for a definition of 'information'. There are certainly other situations imaginable in which a need for a subsequent action requires support. Overall, the definition certainly points at some crucial situation in which the notion of 'information' plays a central role but restricts its scope unnecessarily.

4.3.8. Formalization of Information

There have been attempts to formalize conceptualizations of 'information' in information science; see, in particular, Mizzaro's theory of information in [63] and [64], which provides an interesting approach from the viewpoint of information retrieval that relies on a prior understanding of 'information'. Such attempts are inevitably accompanied by reductions in the conceptual complexity of a socio-cultural understanding of the primary concepts. The semantic conception of 'truth' does not capture all facets of the understandings of the concept in real life. Instead, it is designed to capture the fundamental properties that are needed to build mathematics on it. Approaches that move toward a formalization of 'information', however, do not constitute a formal system in the spirit of the theories described in this section, and a respective theory is out of reach at the moment.

The most promising starting point for specifying the basic symbols of the cognitive sciences is the famous "fundamental equation" of information science that was discussed by Brookes [65] and successively refined to its famous form [61]:

$$K[S] + \Delta I = K[S + \Delta S] \tag{8}$$

This equation

> ...states in its very general way that the knowledge structure $K[S]$ is changed to the new modified structure $K[S + \Delta S]$ by the information ΔI, the ΔS indication the effect of the modification. (*cf.* [61]; p. 131)

Brookes has included background ideas and annotations with this statement (8) (*cf.* [61]; p. 131). In the course of his exposition, he explains the principles behind this formally condensed statement. He points out that this equation must not be viewed as a simplification but as a *representation* of more

complex insights. In this sense, it is meant to transcribe some general insights into the 'nature' of the concepts of knowledge and information.

Brookes' "fundamental equation" provides the most abstract *formal* specification of the interaction of data, information and knowledge and has attained broad acceptance in the information science and retrieval community. Our considerations provide a conceptual clarification of the significance of the fundamental equation beyond its original background and a guideline for a realization of the abstract and denotational statement (8). The respective clarifications are, at the same time, the first step for any further modeling, insofar as they determine the abstract properties of and interrelations between the concepts that must be modeled. This results in a specification of the *principles* behind (8) in a theoretical framework. We call these basic specifications *principles*, thus avoiding the word *axioms*, because we are well aware that in light of modern logic, an axiomatization would require a formal language along with a syntax to formulate the axioms.

5. The Philosophical Background

The treatment of the concept 'information' in information science confirms that the core concepts needed for a conceptual clarification of 'information' are indeed 'data' and 'knowledge'. This section is devoted to philosophical investigations of the epistemic status of these concepts and their relationships. The basic situation is comparable to the situation in logic concerning the concepts of meaning, validity and truth. Tarski [19] has explicitly referred to foundational philosophical positions, namely the semiotic approach, as the philosophical ground for his pioneering theory of truth that ties truth to meaning. Tarski explicitly wanted to avoid an ad hoc approach or one based on a specific background. A philosophical reflection therefore seems both inevitable and indispensable.

Our approach is committed to semiotic theory in the tradition of C.S. Peirce's pragmatic philosophy [59]. Pragmatism (or pragmaticism, as it was later called) reacts to deficiencies in the philosophical tradition, especially where the gap between pure epistemology and practice could not be bridged in a philosophically sufficient way. We will show that the concept of information can indeed be clarified based on this context.

Even a rough outline of these philosophical insights would be outside the scope of this work. Thus, we will instead sketch some basic principles of this approach that may reveal the influences of this position on the theory of information we are developing in the sequel. We intend to introduce the main concepts and to evoke the central ideas of the position. This discussion is not intended to be a careful philosophical analysis but rather a brief review of the basics of Peirce's philosophy. Readers who are not acquainted with the fundamentals of this approach or who are interested in the topic should consult introductory textbooks such as [66–71].

5.1. Pragmatism

According to the philosophical tradition originating from the (idealistic) position of Kant, knowledge is composed of the perception and subsumption of concepts into categories. This is an ability performed by the transcendental subject (cognitive spontaneity; see [25]). While sharing this general approach (at least in principle), Peirce emphasizes that the actual establishment of knowledge is performed by

individuals and results in an orientation in the 'world'. This is seen as a process in which first concepts are formed and then knowledge is established. These concepts are closely tied to a person's intended possible actions. This idea is expressed by the *pragmatic maxim*:

> Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object. (*cf.* [59]; paragraph 5.402)

According to the pragmatic maxim, concepts are constituted by the effects they may evoke. These potential effects then form the basis for our conception of objects, which gives rise to knowledge. It remains to be seen in which way, or, more precisely, on what basis this is performed.

What initiates our awareness about phenomena are *signs*. Signs are considered the basic constituents of all epistemic processes. Hence, knowledge is represented by signs. Consequently, this view demands a theory of signs along with a theory of understanding and interpreting them, which is developed in the field of semiotics.

The interpretation of epistemic processes as part of a general theory of signs, on the other hand, necessarily requires a foundation for epistemic considerations. According to the classical philosophical tradition (especially in the spirit of Kant's epistemology), this requires the detection of a system of *categories* that determine the fundamental aspects of any possible dealing with signs. Peirce introduces three universal categories that are always present in every epistemic process. They are described in his third lecture on pragmatism in 1903 as follows (*cf.* [59]; Vol. 8, paragraph 328; A Letter to Lady Welby):

1. *Firstness* is the mode of being of that which is such as it is, positively and without reference to anything else.

2. *Secondness* is the mode of being of that which is such as it is, with respect to a second but regardless of any third.

3. *Thirdness* is the mode of being of that which is such as it is, in bringing a second and third into relation to each other.

Understanding may now be characterized as a principally uncompletable process of the effect of signs for an interpretant. This process is called *semiosis* (*cf.* [59]; paragraph 5.484).

> [Semiosis is] an action, or influence, which is, or which involves, a cooperation of three subjects, such as a sign, its object, and its interpretant, this tri-relative influence not being in any way resolvable into actions between pairs. (*cf.* [59]; paragraph 5.484).

This definition implies a triadic understanding of signs as claimed by the categories. Because of their status as universal categories, they are basic for all epistemic processes. The theory of signs must reflect this. Hence, the theory of signs as described above is also subject to a triadic relation. This has been pointed out by Buckler (*cf.* [72]; p. 99):

> A sign, or Representamen, is a First which stands in such a genuine triadic relation to a Second, called its Object, as to be capable of determining a Third, called its Interpretant, to

> assume the same triadic relation to its Object in which it stands itself to the same object. The triadic relation is genuine, that is its three members are bound together by it in a way that does not consist in any complexus of dyadic relations.

It is important that there is not only one stage of triadic interpretation of signs. In principle, a "semiosis" is a multi-stage process. A sign in its triadic specification may be an object of consideration with a specific viewpoint in itself. This turns one triadic sign into a representamen for another process, which is another triadic sign with another object and another representamen. It is worth mentioning at this point that the *interpretant* in Peirce's theory of signs is the *sign* created in the mind of a person and not the person itself.

In general, his categories and his semiotic analysis are meant to provide the means to bridge the gap that Peirce identified in the Kantian epistemology between a concept and its relation to (possible) actions. It is the process of the semiosis that overcomes this fundamental restriction detected in the philosophical tradition.

According to pragmatic semiotics, signs, concepts, and objects must be considered together with their relations. Concepts must not be separated from the process of establishing knowledge and, according to the pragmatic maxim [59], thus may not be thought without their possible consequences or actions in our imagination.

Peirce's theory of signs may in short be explained by the following statement in Buckler (*cf.* [72]; p. 99):

> A sign, or representamen, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the interpretant of the first sign. The sign stands for something, its object. It stands for that object, not in all respects, but in reference to a sort of idea, which I have sometimes called the ground of the representamen.

Philosophical ideas structure the domain of things that may be considered. These structures implicitly underlie all phenomena and thus must be considered in order to establish a cognitively adequate (information) model. Because the main focus of this paper is not on problems of epistemology, we will interrupt the discussion of the philosophical background at this point. It is our concern to base our theory on clear philosophical insights rather than to contribute to the philosophy of pragmatism.

In this context, the present work is designed to face this reproach and to develop a methodologically justified characterization of information. The investigation of consequences that may serve as a concrete basis for our intended application requires a transformation of epistemic principles into conceptualizations that allow a more practical treatment. Such an interpretation will be presented in the following section.

5.2. Morris' Analytical Reductions

Whereas Peirce's categories were meant to be universal philosophical categories underlying and guiding every epistemic process, a subsequent, purely analytical reinterpretation of the semiotic

relationships based on the three categories has been established by Morris (*cf.* [73]). In the following discussion, we adopt this analytical reduction. Accordingly, semiotics as the general theory of signs has three subdivisions [74] (see also [75]):

(1) *syntactics*, the study of "the formal relations of signs to one another";

(2) *semantics*, the study of "the relations of signs to the objects to which the signs are applicable";

(3) *pragmatics*, the study of "the relation of signs to interpreters".

In this analysis, some possible relationships are missing that could also be considered the result of a reduction process. One could certainly think of the relation between an interpreter of a sign and the objects to which the signs are applicable ([76]). However, this conclusion may be deduced from the composition of the pragmatic and the semantic relationship, leaving room for further investigations based on these dimensions. As the significance of 'sign' in item (3) may not be restricted without affecting the entire understanding of semantics, one could also investigate the relationship between an interpreter and the semantic relationship itself. This will be of special interest in this paper given the semantic relationships presented by a sign as well.

Semiotics, however, only constitutes the abstract background for our considerations; it is a tool that helps us understand what information is or could be. Hence, a re-interpretation of those dimensions in the field of information is required.

6. A Semiotic View of Information

In this section, we discuss the semiotic nature of information and of the related concepts of knowledge and data. We will show that the semiotic approach provides a theoretical basis for a unified view of data, knowledge and information, from which a conceptual clarification of information finally can be deduced. The common basis of these concepts is provided by the abstract concept of a *sign*, which is considered an ontological unity.

The philosophical foundation has provided the epistemological background, but the general theory of signs cannot directly provide an answer to our conceptual analysis. It is much too abstract to be fruitful for investigating the very nature of the concept of information. Thus, we must determine how the general approach differentiates in the context of information.

Signs, in an epistemic context, are subject to analytical considerations, according to Morris' semiotic dimensions. Because these semiotic dimensions are abstractions derived from Peirce's categories, the universality of the latter as a whole cannot be circumvented and is always present in all mental activities. All these dimensions are closely interrelated, so isolating just one dimension of a comprehensive semiotic analysis can only be done artificially and only for analytical purposes. One may certainly focus on projections of the whole to one of its dimensions, but these are then restricted perspectives that neglect the other dimensions which are nevertheless associated with the object as well. This results in the following conceptual coordination, which cannot be discussed in an isolated way. To relate data, knowledge and information to the semiotical dimensions, respectively, is not new as we have seen above. For example, already Morris [74] has information related to the pragmatical dimension of signs. But beyond a systematic coordination, we show what this coordination means for conceptualizations of data,

knowledge and information: it constitutes the grounds for the "severely neglected connection between theories of information and theories of knowledge." (Capurro and Hjørland [30]; p. 356).

6.1. Data Denotes the Syntactical *Dimension of a Sign*

In the semiotic view, *data* denotes the organized arrangement of signs with an emphasis on the structural or grammatical aspect. However, there must be more in our context. Arbitrary arrangements of signs are not considered data. Data are always derived from an understanding of a part of the world, notwithstanding the fact that the result is basically a sequence of pure signs.

Given the pragmatic maxim cited above, the concept of data must be understood with respect to its actionable intentions, *i.e.*, its usage. According to their syntactic dimension, data are not interpreted but interpretable. The adherent interpretation, however, is external to the syntactic structure, although data are bound to it; data provide the raw material for subsequent interpretation (which will turn out to be significant for knowledge and information).

This aspect has several implications. The creator of data must ensure that a subsequent interpretation is feasible. This is done by using an organizational structure, *i.e.*, a grammar. Such a grammar is normally endowed with a shared interpretation within a community. It should refer to an understanding that can be taken for granted (at least to some extent) in the community to which the intended content is addressed. Logical languages are examples. They are addressed to the mathematical community and they are (and must be) interpretable by members of this community (*i.e.*, mathematicians). Mathematicians do (in principle) understand what is meant by a given formal expression [77]. In contrast, think of a person who has invented a new language. In general, this language cannot be understood by others, and no content may be extracted from it. The history of science has produced such phenomena, which have remained bound to a single individual's intention with no influence on the scientific community.

Data are the pure, raw materials on which knowledge and information may be built, structured and organized. Data form the indispensable material for subsequent 'in-formation', *i.e.*, the expression that represents knowledge. On the other hand, the concept of data is just one dimension, so this concept cannot be understood outside of its interrelation with the concepts necessarily associated with it, particularly the other semiotic dimensions of our given context. From this point of view, knowledge—the semantic dimension—adds specifications to 'sign', and data can only be artificially thought without it [78]. So data can only be understood in this context. It is the view on material of something being (in-)formed. In the same sense in which one cannot separate material from form, data cannot be separated from knowledge and information.

Moreover, *data* are exchanged through the channel in Figure 2. Data are the carriers for knowledge as well as for information. Data are their manifestation, the way they can be communicated. On the other hand, a systematic loss is unavoidable. A price must be paid for reducing the entire semiosis to one of its isolated dimensions. We will see to what effect the neglection of the other dimensions may lead.

6.2. Knowledge Denotes the Semantical *Dimension of a Sign.*

According to Morris' analytical reductions, semantics is a 2-place relationship. If knowledge is of the semantic dimension, it is to be shown what concepts hold those two places and which semiotic aspect is

not addressed by knowledge. In the first place, we find data. As we have seen, data form the basis on which knowledge is represented or expressed. In the second place, we find data endowed with meaning, or interpreted data. It remains to be seen what 'interpreted' should mean.

To begin, we note that reducing the process of the semiosis to a mere 2-place relation results in an abstraction from the Peircean category of thirdness. "The third is thought in its role as governing Secondness. It [...] determines the idea and gives it body. It is informing thought, or cognition. But take away the psychological or accidental human element, and in this genuine Thirdness we see the operation of a sign." (Lowell Lectures, Peirce [59]; paragraph 1.536-537). In our terminology this means that the cognitive system (a human mind) "governs" cognition and determines its results. Thus, this "thought" is bound to the cognitive system. As for syntax, reducing this process (the semiosis) to a 2-place relationship amounts to neglecting the involvement of the cognitive system and leads to consequences for its analytical abstraction in semantics as well. Two possibilities can be conceived for the specific kind of abstraction realized by knowledge:

(1) It is abstracted from the process of the semiosis as a whole and only its result is under consideration.

(2) The reduction of the dimensions reflects intersubjectivity and, as such, must not depend on a concrete interpreter.

Whereas the first alternative may easily be achieved by simply neglecting the semiotic process as a whole, the second involves some universality that must be specifically justified. We find both aspects represented in the context of knowledge, and the way it will be handled is the main difference between knowledge and information.

In this context, the abstraction process amounts to analyzing the grounds on which a private conviction (the notion to stand for the Greek *doxa* [79]) can be qualified as knowledge (see the section on knowledge for details). This process must be acknowledged in some way *beyond* this conviction. However, a semantic relationship puts aside the very conditions under which this abstraction process can be performed. It is only the *result* that is of interest when speaking of knowledge. The characteristics of its genesis represent the thirdness, or the pragmatic dimension, which is abandoned. Thus, we must still ask on what grounds we are legitimized to abandon this dimension.

The abstraction process must be able to admit such abstraction, and we must find a substitute for the process *inside the result*, which nevertheless must reflect essential facets of the process. We are therefore looking for a concept that must be independent of subjective views and, at the same time, express a shared intersubjective agreement. Its legitimacy must then be determined in the internal constitution of the understanding of 'knowledge'.

A candidate for such a conception is truth or some form of validity. Indeed, knowledge is generally understood to be certain (see either the abstract characterization of knowledge given in the next section or the necessary condition for its genesis in an epistemological sense [80]). This certainty may be truth (*cf.* [81]; p. 34), or it may at least be justified in some general sense (see [15]). In any case, the involvement of (some kind of) certainty compensates and at the same time reflects the reduction of the semiotic process to two dimensions without neglecting this process in total. Knowledge is an expression of a result (something being certain) and claims that the process has been conducted in a legitimate way.

We must then ask what kind of (abstracted) relations may actually result from such an abstraction. Pure subjective convictions would certainly not count for knowledge. There must be more, something that guarantees—or at least claims—(intersubjective) acceptance. This is the role of validity.

In this sense, we may analyze characteristics of the *kind of abstraction* involved in the actual generation of a conviction and its subsequent attribution as knowledge. Accordingly, the abstraction leads to various degrees of certainty. In particular, it may be

- universally valid;

  This would be ideal for a pure semantic characterization—a characterization that does not take into account who produced it and is, in general, the pretension of *truth*. However, even Tarski's semantic theory of truth [19] in mathematics has not experienced general acceptance as a universal methodology and remains bound to the Hilbert-Tarski-style of mathematics. See, for example, constructive mathematics in the sense of Brouwer [82] for an alternative approach.

  There are no other apparent grounds for a universally accepted methodology; thus, this claim must be considered a "regulative idea" (in the sense of Kant) and may only be approximated in reality.

- dependent on presuppositions;

  If we give up a unifying, universal view on truth (as the different conceptions of truth indicate) we end up with a diversity of conflicting understandings. Accordingly, the unifying pretension of validity vanishes as well. This implies a community that shares presuppositions. Hence, the abstraction determining the semantic nature of the knowledge is only acknowledged by and accepted in this community. As a result, we find a diversity of competing understandings. Thus, knowledge represents a system's view only; it is bound to a shared understanding within a community.

- only subjective;

  In general, this does not count for knowledge, but may qualify as the starting point for knowledge. In this sense, it is the basis for any process resulting in knowledge (*cf.* the abstract characterization of knowledge described later).

These degrees of certainty lead to several dimensions or degrees of justification. Whereas 'true', 'valid' or 'justified' suggest a universal claim of justification, there may exist subjective knowledge with certainty that is guaranteed on subjective grounds solely. The next section will address this issue in more detail.

6.3. Information Denotes the Pragmatic *Dimension of a Sign.*

Information, as the pragmatic dimension, demands an interpretation process whose legitimacy must be considered as well. This will turn out to be a crucial point. In contrast, knowledge may delegate legitimacy to the whole system to which it belongs. On the other hand, it is a cognitive system that performs this interpretation [83]. Hence, information is bound to such a (cognitive) system, which in turn is an *external* one, as we have seen in a previous section. This system accepts the grounds on which the semiosis is performed and shares the validity produced by the interpretation

associated with the underlying material (data) (*cf.* the remarks on knowledge and its dependency from a system's presuppositions).

However, legitimacy remains external. Thus, the interpretation associated with information is based on some external justification as well. This justification is a property of the respective external (cognitive) system. Inside a system, we may put questions of legitimacy aside, because the system stands for some universal commitment that must not be repeated for each single instance. In other words, it is *knowledge* inside this cognitive system that is bound to its specific kind of validity. Hence, it may best be described as external knowledge.

Because of this externality, knowledge requires some appropriation if it is not to remain external. Such an appropriation is not arbitrary but 'purposeful'. The appropriation is driven by an intention and triggered by a concrete doubtful situation that should be resolved (see [59]; paragraph 5.372). It is this very aspect of knowledge that in another context is vaguely described as the "biased" nature of information (see, e.g., [58]; p. 265). Dretske [12] states:

> It is common among cognitive scientists to regard information as a creation of the mind, as something we conscious agents assign to, or impose on, otherwise meaningless events. Information, like beauty, is in the mind of the beholder.

Moreover, this appropriation necessarily involves a communication act as described in Figure 2. To speak of 'information' therefore requires two different cognitive systems: the one that produces the knowledge item and the one that tries to appropriate it. But what actually goes through the 'channel' in Figure 2 (or, in other words, what is communicated between the two cognitive systems) is only data, the syntactical dimension of the sign. The other dimensions are determined by the system's property and thus are not attached to or otherwise connected with the sign. Information as external knowledge is presented to the communication system simply as data, without this justification. The associated interpretation and justification are the system's properties and, as such, are not present in what is communicated[84]. The mere exchange of data—the pure communication act—must be complemented by an attempt to re-create the other semiotic dimensions that had been associated with that data in the external system. This is what is meant by appropriation. Because it is indeed a re-interpretation, this process has the potential to either succeed or fail. The result of the process may either fit into the knowledge system or generate inconsistencies.

An example from mathematics may illustrate this point. Mathematical theorems are considered to be generally justified (*i.e.*, of a pure semantical nature) and thus are not subject to the considerations discussed above. A proof in mathematics should neither depend on subjective presuppositions nor on subjective convictions. It should provide a universally accepted justification. Something is either a proof or not, and there should be no doubt about that [85]. However, consider the following statement (see Troelstra/van Dalen [86]; p. 22):

All functions from the interval $[0, 1]$ to the reals are uniformly continuous.

Is the statement true or false? The correct answer must be that it depends! It depends on the kind of mathematics one is committed to. In classical, Hilbert-style mathematics, it is clearly false. But in intuitionistic mathematics in the sense of Brouwer, it is a provable theorem (see [87]). (It should

be mentioned, though, that the meaning of the terms in the statement is slightly different in the two mathematical approaches.)

This is exactly the problem we have discussed above. Suppose you are uncertain about the validity of the statement and look for information on the matter. Suppose you are committed to classical mathematics, and you come across some website claiming that this statement has been proven. You make this statement part of a proof of a new theorem of your own. On this basis, you should most probably then be able to prove that $0 = 1$ as well, which counts as a contradiction. This is because information has been taken out of an external context with different presuppositions (intuitionistic mathematics); it has been communicated as pure data (the expression given above), and you have endowed it with your standard interpretation, as provided by classical mathematics, to turn it into knowledge.

The problem is not the statement; it is knowledge of intuitionistic mathematics but not classical mathematics. External knowledge has been turned into information in a special situation in which you have looked for support. However, all this leaves the underlying material—the expression of the statement and the data—untouched. It has then been appropriated by (re-)interpretation in classical Hilbert-style mathematics. The result is a state of inconsistency through which the whole knowledge system has been dissolved.

This example shows the interrelation between information and knowledge. It demonstrates that knowledge and information are indeed closely linked. The underlying 'material' (the statement) remains the same. The difference is the "doubtful situation" (Peirce) that gives rise to contact external cognitive systems. Only in such a situation may we speak of 'information'. In this situation, information is nothing but *external* knowledge, but it is knowledge. We can conclude that information and knowledge are the same and differ only from the perspective on their respective contexts.

The example given is from mathematics. I have chosen this one because it originates from the scientific field in which problems of this kind are least expected. However, the example demonstrates that the necessary (re-)interpretation associated with information constitutes a principal problem we cannot escape from. Similar phenomena may happen all the more in other fields and especially in everyday life. Wikipedia is a modern example for potential hazards when used in an uncritical way.

We may summarize our characterization as follows. Sharing the given presuppositions of a knowledge conception for a given item of information along with the necessary process of appropriation turns information—which is at first external to the knowledge system—into knowledge; otherwise, it is to be rejected. This is because its internal interpretation cannot be acknowledged from the perspective of the knowledge system. Even worse, from a systematic point of view, internal (re-)interpretation has the potential to dissolve the knowledge system as a whole, leading to internal inconsistencies or conflicting with the determining presuppositions. This means that 'information' relates to *some* external knowledge that is confronted with a knowledge *system*. In addition, a process of appropriation is indispensable in any context in which we may speak of information (*cf.* the subsection on 'Re-interpretation of conceptualizations of information' below for details how the approach presented here is different from other conceptions of information).

7. Knowledge as a Conceptual Basis for Information

In this section, we return to the question of what information *is*. The first answer is that knowledge and information are essentially the same. They differ only from the perspective of a knowledge *system*. Only from the system's view, the pragmatic nature of information appears; it must give rise to an appropriation process. In the context from which information originates, it is simply knowledge. This means that the difference between knowledge and information is *not* on the conceptual level. The concept of information seen as "knowledge communicated" in Capurro and Hjørland [30] is not only meant as a 'lexical definition' (Chalmers [88]) serializing words which does not tell what this *combination* of words actually means. Instead, 'knowledge communicated' "indicates a severely neglected connection between theories of information and theories of knowledge" (*cf.* [30]; p. 356). As this 'indication', however, was rather considered a program for future investigations and has not been worked out in detail (*cf.* also Capurro [89]), this paper is intended to fill exactly this gap. Thus, in order to understand what information *is*, we have to analyse "theories of knowledge". Accordingly, we proceed by considering the concept of knowledge. An analysis of knowledge should then illuminate information as well.

7.1. The Concept of Knowledge

The characterization given in Plato's *Theaitet* [90] still constitutes the starting point for clarifying understandings of the concept of knowledge. In this dialogue, Plato discusses the most influential specification of the concept of knowledge as "justified true belief" [91]. At the same time, he demonstrates the inadequacy of this characterization. We may conclude that there remains some uncertainty with respect to this specification, and we may not take it as a universally valid clarification.

It is not that Plato did not discuss these criteria. At first glance, it seemed that we would indeed end up with a reasonable specification. In the end, however, his most disputable approach was misunderstood as providing a fixed characterization that could be seen as a definition. A closer look shows that we are confronted with externally combined facets of aspects of the concept of knowledge that neglect their internal relationships.

Already in the *Theaitet*, the results of this treatment of the criteria are obvious. At the end, the participants of the dialogue agree that further consideration is necessary to grasp the concept of knowledge. Accordingly, Wieland states that Plato insists on the difference between knowledge and belief, even if he must admit that he is not able to separate the two concepts precisely (see Wieland [92]; p. 280). Thus, the problem of an exact specification of the term 'knowledge' was noted by Plato, but he has not provided a satisfactory answer. (It should be mentioned, though, that in Plato's *Menon* [93] a less critical tendency may be observed. In addition, we think that the characterization of knowledge given above may further illuminate the matter, but this is outside the scope of this discussion.) The famous paper by Edmund Gettier [94] brought logical methods into the problem, resulting in an intense discussion of the concept of knowledge.

Analytic descriptions [95] coordinate conditions in a truth-functional sense: a list of characterizations is an independent list of properties that does not reflect mutual dependencies. This strongly recalls pre-Fregean methods of describing conceptualizations established by the addition of attributes [96]. Such an approach to an understanding of a conceptualization, however, can be considered an attempt to treat

a Platonic concept in an Aristotelian sense. Whereas in Plato the notion $\lambda\acute{o}\gamma o\varsigma$, describing a never completely dissoluble process of understanding, plays a fundamental role for any conceptualization, an Aristotelian approach could at least envisage to capture the contents of a concept by specific characterizations. It is obvious that this would result in a problematic situation.

In this sense, a specification given by a *set* of criteria would not achieve a satisfactory solution. If we are not to abandon the program of an analytic description of knowledge, we either remain bound to a principally inadequate collection of descriptors, or we must extend the means of description.

This second approach will be pursued in the following discussion. We reconsider the traditional concept of knowledge. What constitutes knowledge must not be interpreted as constituted by independent conditions. Instead, we suggest a characterization of 'knowledge' in which the defining properties are interrelated in their internal constitution.

As a first step, we postulate an integrated view. *Justified true belief* is the best possible *analytic* characterization of the concept of knowledge. However, this characterization has some deficiencies. The claim for truth must be honored in a justified way and must not be an external attribution. Similarly, truth must be *recognized* truth instead of an external attribution. The recognition of truth must be accounted for in a justified manner. In mathematics we see an example of such an interrelationship: the truth of a statement must be demonstrated via a proof.

Hence, an analysis of conditions must be complemented by a specification of how these conditions are interwoven. Every other approach will inevitably end in an aporia, as in the *Theaitet*. The key problem in Plato's specification is the separation of truth and justification—that is, the idea of two mutually independent characteristics. In accordance with the considerations presented above, the suggested solution is to bind justification to the *process* that leads to the acceptance of truth.

This hints at a characterization of knowledge as being of the form $\mathcal{F}$*(justified, true, belief)* [97]. The problem is the degree of intersubjective justification associated with this process. This implies an aspect of thirdness already involved in the conception of knowledge. Although the results—the knowledge items—do not reflect this thirdness, it must be present as a condition of the system. However, this presence suggests an additional task. By this sort of characterization, we are inevitably required to determine the operator $\mathcal{F}$ in order to achieve an adequate characterization of knowledge. In the following, we will call this operator an *interlacing* of the constituents.

In contrast to Plato, where truth is bound to the "first world" of ideas, we now must face different conceptions of truth. We must therefore either commit ourselves to one of these truth-conceptions or admit any such commitment. We have chosen the second possibility. Accordingly, we weaken the concept of truth and replace it with the more general concept of 'validity'.

Thus, we may summarize the central thesis of the first section as follows:

Knowledge is $\mathcal{F}$*(justified, valid, belief)*.

A more adequate understanding of knowledge must integrate the given criteria into an interlaced view $\mathcal{F}$. We cannot just claim the validity of some insights with no justification. Instead, the validation must be presented in a reproducible and intelligible way. This is the first aspect of an interlacing of validity and justification. As we have seen, knowledge is of dimension-reduced semiotic status, and thus it is inevitably bound to the situation from which it is abstracted and isolated as a phenomenon.

Accordingly, the $\mathcal{F}$ in this characterization also includes the dependency of a system with which we are able to dispense. This is the sense of knowledge. This is the aspect that makes knowledge transferable, applicable, and communicable—namely, that it may *claim* a sort of justification but not express it explicitly. Knowledge remains dependent on the conditions of its production. Otherwise, it would be fleeting and transitory, only valid at the time of its establishment. Such a conception of knowledge is, for example, represented by the mental-state-theory developed in the tradition of the so-called "Oxford realists" (Cook Wilson [98], Pritchard [99], and Austin [100,101]).

The concept of validity plays a dominant role in our characterization (see also the section on the semiotic view above). In any case, knowledge must be different from arbitrariness. Hence, a *reason* in form of a justification of its recognition must be presented in order to qualify an insight (or a conviction or a belief) as knowledge; already Plato has demonstrated that 'valid belief' is not enough. In this sense, validation is primary; justification is always the legitimate attribution of validity to an insight. We thus turn to the concept of validity to further clarify the concept of knowledge.

7.2. Truth as a Criterion

It is undisputed that a kind of validity is an indispensable characteristic of knowledge. Mostly, it is articulated as the requirement of truth. Neglecting the validity of a belief hardly qualifies the given belief as knowledge. Hence, the validity may be considered an analytic property of knowledge. The question is how—and in this paper, we specifically ask by what means—validity is interrelated with other attributes to constitute knowledge. As truth may be considered the ultimate goal of any validation, we will initially focus our attention on truth instead of validity. The principal problems connected with these concepts will be clarified concerning truth.

Truth is a very difficult concept that admits the construction of antinomies, the most prominent one being the paradox of the liar:

"Epimenides the Cretan says, all Cretans are liars."

This constitutes a touchstone for every (not only philosophical) conception of knowledge that involves some form of truth. Truth-specific problems as given by the antinomies may affect conceptualizations of knowledge. Insofar as the concept of knowledge inherits 'intoxications' stemming from the concept of truth, can I know that a Cretan says that all Cretans are liars?

In any case, we have to focus on the pitfalls in this area. This is important because consequences may finally lead to the self-destruction of a conceptualization that exposes its contents to arbitrariness. All systems that admit self-referential constructions within their field of application are potentially concerned. In view of the perspective of a foundation, this means that

Self-referentiality must not be admitted in an uncontrolled way [102].

For any foundation of a knowledge system, an account of the reach and applicability of principles that admit construction of self-referential conceptualizations is inevitable to prevent the revocation of validity. Because validity must be closely tied to knowledge, this results in the conclusion that

Any conception of knowledge must control validity.

This conclusion applies a fortiori to the system with which each knowledge item is associated. Moreover, it is a system's property rather than a demand on individual knowledge items. Thus, from the perspective of the conception of knowledge as developed in this paper, we should restate this demand as follows:

Any conception of a knowledge system must control validity.

7.3. Mathematics as the Ideal Scientific Discipline?

Mathematics at the beginning of the nineteenth century may be considered similar to the state of any other field seeking a secure foundation for knowledge. A mainspring of mathematics at that time, the program of Cauchy, was dedicated to the problem of turning the predominant, rather intuitive basis into a precise shape. Cauchy originated a strong methodological approach to mathematics. His intention was to replace the prevalent, rather intuitive conception of mathematics with exact definitions and to develop an analysis on this basis (see [103] and [104]). This program was completed to some point by the work of Frege and Whitehead-Russell [105].

Through the widely accepted foundation of classical mathematics via the language of predicate logic, mathematics has gained a framework to represent concepts precisely. This language satisfies the requirements of conceptual accuracy and clarity in the representation of (individual) mathematical insights. Cauchy's program of exact specifications of problems and proofs resulted in a specification language for the conceptualizations that turned respective subjective understandings into a normative representation.

Tarski provided a conceptualization of meaning that is interlaced with a conception of validity: his semantic conception of truth for "formalized languages" [106]. This conceptualization is specifically tailored to the representation language introduced by Frege, which circumvents the self-referentiality of truth assignment by methodical exclusion; self-referentiality of truth simply cannot occur by the very conception of this truth-definition. We observe the vision of a conception of meaning as an explicitly semantic one that, as such, detracts individual understandings from their subjective validity and canonizes them. Overall, we observe an intrinsic interlacing of meaning and this conception of truth as some special form of validity.

7.4. Knowledge in Mathematics

We now return to the concept of knowledge as justified valid insight (to avoid the term 'belief' in this context; see [107]) as presented above. We have developed an understanding of knowledge that necessarily must integrate these criteria via an operator $\mathcal{F}$. Overall, mathematics has

- a constitution of objects in a formal language (Frege's *Begriffssprache*) as data
- a concept of meaning specifically tailored for mathematics along with
- a conception of validity, *i.e.*, truth (see [19])
- a constitution of validity that excludes self-referential constructions

- logical inference rules preserving truth
- a dependency structure provided by a concept of justification ('proof')

We observe an example of a successful interlacing of validity (Tarski's conception of 'truth') and justification along with its contents. The operator $\mathcal{F}$ describes the integrative conception of meaning and truth for a formalized language that admits a 'calculation' with rules such that the results exactly constitute the truth-preserving relationships between knowledge items. Moreover, an additional condition is satisfied: Tarski's conception of truth excludes the problem of self-reference by methodical exclusion and thus prohibits the construction of the (known) semantic antinomies.

Thus, this approach seems to be a satisfactory solution to the abstract conditions for knowledge. However, as our discussion of knowledge above has shown, even in mathematics there is still a difference between knowledge and information. We may find statements that represent knowledge in the context in which they are established; however, when seen as information, these statements remain inevitably bound to the whole knowledge system from which they are taken. This example aims at the heart of the difference between knowledge and information, showing that they must not be conflated, despite their close relationship.

8. Information

We have argued that information and knowledge are conceptually the same. Accordingly, information is bound to a conception of knowledge that in turn gives rise to a respective concept of information. We have presented a framework for conceptualizations of knowledge that is meant to constitute a universal characterization scheme that must be instantiated by any concrete understanding of knowledge. This will produce the desired characterization of the concept of information. The situation in mathematics shows what such an instantiation of the conceptual framework might look like. To investigate the concept of information further, we must establish specific characterizations of knowledge. Some further clarifications of the concept of information can be given based on the analysis presented so far.

As we have seen, information is some sort of external knowledge that is only available in the form of data. As such, it must be endowed with a conception of validity or truth that might not be compatible with the one basically associated with it. This demand—which at the same time constitutes a principal thread—requires special activities, *i.e.*, a process of appropriation.

8.1. Information and Uncertainty

From the conceptual characterization of knowledge in the previous section, we deduce that information from a *conceptual* point of view incorporates *certainty*. This may well be some weaker form of validity or even reliability instead of truth, but it must be of this kind. So the concept of information includes the aspect of certainty.

But we have also seen that information is often related to uncertainty as well. We are now in a position to explain this relationship. Uncertainty comes into play not on the conceptual but on the pragmatic level. It is the uncertainty concerning the equivalence of the grounds of the justification procedure associated with the information item and a knowledge system, respectively. Additionally, information is bound to

a "doubtful situation", as described by Peirce, which also may be interpreted as an aspect of uncertainty that cannot be eliminated.

Moreover, if an appropriation process succeeds, the doubtful situation is overcome. The appropriation of a suitable information item has filled a lack in the knowledge system, which in turn has been extended. An extension of a knowledge system may be interpreted as a reduction of uncertainty, or at least of the uncertainty that had been produced by the doubtful situation. However, it should be noted that this extension may well be elusive. The appropriation might not result in an incoherence or inconsistency in the knowledge system but nevertheless may be misleading in view of the doubtful situation that triggered the need for information. This must be understood, however, as another aspect of uncertainty that cannot be circumvented in principle. Thus, although the concept of information incorporates conceptions of certainty, information is intrinsically related to uncertainty as well.

8.2. Information and Knowledge

Having seen that knowledge and information are the same and do not differ on the conceptual level, we explore in this section under what conditions knowledge can be transferred into information and vice versa. Accordingly, two perspectives have to be distinguished:

- Information as the basis for knowledge.

  This kind of dependence seems trivial at first: simply neglect or ignore the impact of the pragmatic dimension of information. But information is also knowledge. So this pragmatic dimension is reflected in the system's constitution from which the information stems. Just putting this dimension aside would affect the whole system's internal constitution and, consequently, the basis for the constitution of this item as knowledge as well. Thus, we either must have some legitimate reason to do so, or we turn knowledge into pure belief, which is not as reliable as knowledge (*cf.* the characterization of knowledge presented above). Hence, this cannot be done without disqualifying it as knowledge at all. So the conditions and specific commitment to which the process of knowledge generation is bound may not simply be ignored. Instead, it must be expected that information is taken out of something that may rightly claim to be knowledge.

  Remember, however, that information essentially includes an aspect of externality. Hence, it necessarily remains external and thus potentially beyond our control. In other words, we are not necessarily able to understand *why* some given conviction bears some degree of validity or why it can be legitimately considered knowledge in the external knowledge system. Instead, we may simply trust in and try to appropriate it. Thus, in principle there is no safe basis to turn information into knowledge. This is the reason for the aspect of uncertainty necessarily associated with information.

  Moreover, for knowledge based on information, there is necessarily an interpretation process associated (remember that only data is exchanged). Such an interpretation process has to address the problem of coherence or consistency of the possibly different justification processes associated with the information item (the data) and the knowledge system under consideration, respectively. In any case, it must be observed that no incompatible views are merged. This is exactly the task of the appropriation process.

- Knowledge as a basis for information.

  Knowledge—which must be knowledge inside a knowledge (or cognitive) system—may only be turned into information in view of another knowledge (or cognitive) system. However, an internal constitution—its internal commitments—predetermines what could be considered knowledge within the system and is thus involved in the constitution of knowledge. One might think of attempts to communicate these commitments in (meta-)communication. This may indeed be successful, to a certain extent. But an appropriation process is needed to accommodate it anyway, which may be supported—but certainly not substituted—by this additional communication level.

Both relationships are considered in practice. While the former especially emphasizes the *generation* process, the latter stresses the *usability* of previously compiled information under given circumstances.

8.3. Re-Interpretation of Conceptualizations of Information

In this section, we show that our approach is, in fact, in accordance with common, basic understandings of information. To demonstrate this, we refer to the conceptualizations presented above and show how they fit into our context. To do so, we summarize the characterizations and comment on them from the point of view developed in this paper. These remarks are meant to complement the longer expositions in the previous section.

This section, however, pursues also another intention. First, we show that our approach presents a unifying perspective from which all these characterizations receive a quite natural and canonical (re)interpretation. But the following discussion should also provide strong indication that the conceptual analysis given in this paper has the potential to constitute the 'tertium comparationis' to compare conceptualizations of information. Our approach could thus provide the conceptual fundament to highlight their similarities and to demonstrate differences between them in a concise manner. However, to work out similarities and differences between even the most influential approaches in greater detail would constitute work far beyond the scope of this paper (Schrader [108], for example, has found about 700 definitions in the context of information science). So we confine ourselves to the conceptualizations presented above.

(1) Information is [...] a difference that makes a difference.

  This characterization suggests that we need a "doubtful situation", one that is not already covered by the contents of our knowledge system. In such a situation we need "a difference", some additional external knowledge item (information) that is not contained in the knowledge system. The intention is to gain hints to overcome the crucial situation that triggered the need for information. This means that it should indeed "make a difference", or properly extend our knowledge base.

(2) Information is [...] the values of characteristics in the processes' output.

  The "process" mentioned in this statement may be understood as referring to the process of information seeking and subsequent appropriation of external knowledge. Both kinds of processes are involved in the steps to dissolve the "doubtful situation" that is the starting point for the request

for information. Of interest, however, is the result of these processes, the "output". As a result of the information-seeking process, we are confronted with mere data. The "characteristics" of data must be exhibited and (hopefully) evaluated in a positive way, such that the data may contribute to a solution. In other words, its "value" has to be established. This is what appropriation must perform, such that the "doubtful situation" vanishes.

(3) Information is that which is capable of transforming structure.

This item emphasizes the expectation of information. As stated in point (1), information must at least have the potential (being "capable") to dissolve the "doubtful situation" by extending the knowledge system appropriately ("transforming structure"). If this does not happen, we cannot speak of information.

(4) Information is that which modifies [...] a knowledge structure.

This statement is similar to statement (3), but concentrates on the effect of information on knowledge systems ("structures"). "Capabilities" are not the focus but the result, the actual extension of the knowledge system ("modifies") after the appropriation of information from some other source.

(5) Knowledge is a linked structure of concepts.

In this paper, we have shown that the semantic dimension of knowledge does not mean that a dimension is totally missing (see the discussion at the beginning of this section). Instead, it must be subject to a legitimate abstraction, which is only possible if it is able to rely on the respective grounds of a system's constitution.

Point (5) suggests that the necessary systemic character of knowledge is a consequence of its semantic nature. It argues that the *system* must not merely be some amorphous compilation of knowledge items without internal structure but must provide the basis on which the abstraction can be performed, which is not possible without this internal constitution of the knowledge system.

(6) Information is a small part of such a structure.

This item supports the view that information must be knowledge—external knowledge, to be precise, but knowledge nonetheless. It cannot be less; information cannot be pure belief or even mere data. On the contrary: it must have a background in some (external) knowledge system. Subjective belief with no indication of justification remains arbitrary and certainly does not count as information. Information must be more; it must at least indicate its origin, including some kind of justification (which, however, has still to be appropriated).

(7) Information can be viewed as a collection of symbols.

Statement (7) hints at what can only be communicated or transferred between cognitive systems: it is data, or the syntactical dimension of a sign. It concentrates on the carriers of information and emphasizes that we do not have more at first hand. However, we do know with whom or what the communication process has been performed. By exploiting the necessary setting of this basic

situation as given in Figure 2, we may infer more, such as whether the data indeed stem from an external knowledge structure or from some other source.

(8) $K[S] + \Delta I = K[S + \Delta S]$

This is again the famous "fundamental equation" that illustrates the basic situation in which we may speak of information. Aspects of this equation can be found in the discussion of statements (1) through (7). "ΔI" may be interpreted as the "small piece of such a structure" in (6), "$K[S]$" is the knowledge system and "$K[S+\Delta S]$" is the effect of "ΔI" on the the knowledge system "$K[S]$" (namely that information causes an extension of the knowledge system and would not otherwise qualify as information). Moreover, the "ΔI" must be subject to an appropriation process, which turns it into something different: "ΔS".

We have shown that this equation incorporates—in coded, symbolic form—fundamental determinants of the concept of 'information' along with its relationship to the concepts necessarily connected with it, as described in the previous sections of this paper. In this sense, this paper contributes to the general research program formulated by Brookes (*cf.* [61]; p. 117), who stated:

> The interpretation of the fundamental equation is the basic research task of information science.

This is exactly what we have done in this paper.

(9) tacit knowledge

In this additional item, we again refer to the discussion of "tacit knowledge" and comment on it based on our discussion so far. As mentioned above, external knowledge ("information") is potentially beyond our control and solely bound to the external system's constitution. As this may lead to inconsistencies, special attention must be paid to the conditions under which a comprehension of information into a knowledge system is possible at all.

This problem applies to any compilation of what is called "tacit knowledge" into an integrated whole. Because the different information items may be based on incompatible processes of their respective genesis, the integrated system may easily show incoherence, inconsistency or contradiction such that, in effect, no knowledge system can be established on the basis of the integrated compilation. Instead, "anything goes" (or, in logical terms, "ex falso quodlibet").

It is important to ensure that no incompatible views are merged. This means that all items of such a collection have to undergo an appropriation process. As there may be inconsistencies between those information items, decisions have to be made about how to handle such inconsistencies in case they arise during such an appropriation process [109].

This discussion has shown that the approach presented in this paper conform to the basic specifications of 'information' found in the literature. Moreover, it provides a basis for a coherent view of these specifications. Our approach is therefore fundamental and provides an explanation based on theoretical grounds. This is to be expected from a conceptual clarification of the concept of information.

9. Conclusions

In this paper, we have proposed a characterization of information on a conceptual level. Because our interest was solely focused on a *conceptual* clarification, we have left aside all studies of the functional behavior of information and the like as it is not apparent how they may contribute to our program. We have pursued a very specific view of the totality of situations in which information appears. The semiotic approach in the tradition of Peirce and Morris has provided a well-founded and solid perspective for our analysis. The consequences of this perspective have been worked out in detail in the course of our discussion and have indeed led to a conceptual clarification of 'information'.

According to our analysis, information may best be described as communicated knowledge that is external to a cognitive system and requires an appropriation process to accommodate it in a specific setting. From a semiotic point of view, information is the pragmatic dimension of the same process in which knowledge is the semantic and data the syntactical dimension. It is this interrelation that makes it possible to analyze the 'nature' of information via an analysis of knowledge: they merely stand for different perspectives of the same item. Hence, knowledge is the key to a conceptual clarification of information. Any characterization of knowledge constitutes a characterization of information (on the conceptual level) as well.

Special attention is needed for the relationship between information and uncertainty. No uncertainty is associated with the *concept* of information. This is a consequence of the understanding of knowledge, which is essentially based on a concept of validity. Uncertainty only comes into play via the pragmatic nature of its constitution because of its boundedness with respect to an external knowledge system. It is exactly this externality that constitutes the background for uncertainty. Thus, information is not inherently uncertain, but pragmatically uncertain. It is not uncertain as such, *i.e.*, as a result of its internal constitution, but as a result of the conditions of its usage.

In short, we find that information is essentially the same as knowledge. 'Information' reflects the view of external knowledge, whereas 'knowledge' does not. It is the system's view that turns knowledge into information.

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77. Mathematical practice, however, is sometimes different. As mathematics has a semantical foundation (*cf.* Tarski's conception of truth [19]), it *claims* intersubjective validity; see also the next section for this point. But in practice this validity is not necessarily guaranteed. There are known examples in the history of mathematics where this is not the case. See, e.g., the proof of the 0"'-priority method in logic [113], which initially was not really understood in the community by only studying the paper.
78. *Cf.* logic as a basis for knowledge: there must be an underlying formal language—the/a language of logic—on which logic is able to operate. Furthermore, a form capable of representing elementary knowledge has to be established on which logic can operate. See Aristotle, who began the analysis of the elementary structure of something that is capable of logical deductions: it is the "ti kata tinos", the *something about something*. In Frege's conception of modern logic, concepts are considered as truth-functions themselves and thus, in a direct and immediate way, associate concepts (as 1-place relations) with knowledge.
79. 'Private conviction' will stand for the Greek *doxa* as used by Plato in the context of knowledge (see [90]). For reasons that cannot be fully explained in this paper (see [107] for more details), we have chosen to use this notion instead of 'belief', which is more common in the tradition of the discussion of knowledge.
80. To relate this epistemological view to certainty goes (at least) back to Descartes [114]. A similar understanding has also been adopted by Kant when writing "Endlich heißt das sowohl subjektiv als objektiv zureichende Fürwahrhalten das Wissen." (*cf.* [25]; p. B 850/A 822), and has subsequently been widely acknowledged; see, for example, [115] or [116].
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84. This is the pure communication aspect associated with the dimensions of a sign. But such a communication setting may, in practice, be extended to include facets of the understanding of (at least parts of) the system's properties, the type of validity accepted therein, etc. However, this is another matter and in principle subject to general hermeneutical reflections.
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96. In Lotze [119], Par. 28, it is obvious that a pure "summation" of features turns out to be insufficient for conceptualizations, which is demonstrated by an example from mathematics. However, Lotze is not able to provide an intrinsic characterization of functional dependencies between concepts. It should be noted that one may start with a pure summation and nevertheless end up with a system comparable to first order predicate logic. This is shown by the *Formal Concept Analysis* approach (see, for example, Prediger [120]). However, this approach demonstrates how much technical effort is necessary to prove this equivalence, which is by no means easily seen.
97. See also Lotze [119], §§28 and 110, who opposes the operator $\mathcal{F}(a, b, c, ...)$ to a conceptualization given by a summation $S = a+b+c+d...$ of attributes. However, Lotze is still far from providing a more precise specification of that operator at least outside mathematics. Only Frege's conception of logic (along with Tarski's definition of truth) may be seen as an implementation of this idea. However, it must be noted that Gabriel rightly hints at the most principal differences (see [119]; p. XXV).
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102. This is in contrast to Gödel, who stated that our logical intuitions like truth or concepts are contradictory (*cf.* [121]; p. 131). We emphasize the aspect of control rather than a principal avoidance of self-reference. For example, Cantor's diagonalization method in mathematics (along with logical principles like the excluded third) constitutes a productive form of self-reference.
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109. Another interesting approach is presented in Kanfer *et al.* [123] where "distributed knowledge processes" are discussed. The paper considers "embedded knowledge" which includes a shared understanding by group members. This conception is different from tacit knowledge: "embedded knowledge" is not 'tacit'—just in the contrary, it is constructed collaboratively. Hence we find an extension of the concept of knowledge in alliances.

    It is then discussed how such forms of 'knowledge' may be made "mobile" outside their specific context. This question relates to the conditions under which external knowledge (being information) can be appropriated to constitute knowledge again. Moreover, the authors observe a process in groups that is similar to appropriation as discussed here.

    But there are also differences. The use of unprecise means, for example, such as metaphors were discussed to advance a shared understanding. Moreover, the role of misunderstandings is seen as a "necessary, and in some ways a potentially beneficial, aspect of any collaborative situation".

    It would be interesting to see whether the analysis given in this paper could be transferred to the concept of "embedded knowledge". Many basic concepts seem to have counterparts. 'System's property', for example, could be related to "background needed to understand", or "shared understanding" for 'appropriation'. This, however, constitutes separate work and will in any case be beyond the scope of this paper.
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