Data, Information, and Knowledge: Concepts in Standards, Changes and Conjoint Applications

Evgeny Zinder[0000-0002-4238-8555]

FOSTAS Foundation, Moscow, Russian Federation
EZinder@fostas.ru

Abstract. The paper presents the study of a pragmatic system of definitions of the fundamental concepts triplet: data, information, knowledge (DIK). The need for this study is dictated by the existing chaos in these definitions and the fact that these concepts are becoming more and more significant for modern enterprises. Unclear and inconsistent definitions of DIK lead to shortcomings or loss of the logical foundation of complex multipurpose work demanding correct separation of data processing procedures, understanding information presented by these data, and operations of creating, identifying and preserving knowledge. Problems are amplified by the dynamics of changes in knowledge. Responding to this situation the main objectives of the study include determining the requirements for the desired system of DIK definitions, selection of information sources from wide set of international standards and others normative documents, evaluation of DIK definitions in selected sources and adequate definitions elicitation. Using the many-sided methodology, this research has elicited a system of constructive and compatible standardized definitions of DIK, especially for the enterprise engineering (EE) area. The methods of direct application of this system of definitions, as well as the organization of reverse processes of working with knowledge, information, and data, including the reverse conversion processes from knowledge to information and to data, are shown. The paper also shows the reduced sustainability of DIK definitions given by standards during last years. As a hypothesis, the author proposes that this reducing is caused by the impact of postmodernism dissemination in the ICT and KM fields and evaluates the perspectives of meaningful DIK triplet application in EE area.

Keywords: Knowledge management, Enterprise engineering, Data, Information, Knowledge, System of definitions

1 Introduction

1.1 Characterizing Problems and Choosing the Research Direction

This paper describes the formation of a pragmatic system of definitions of the triplet of fundamental concepts: data, information, knowledge (DIK). The impetus was the existing chaos in the definitions of the DIK, the tendency to change the interpretations of these concepts, and the fact that these concepts are becoming more and more im-

portant for modern enterprises - knowledge based enterprises, digital enterprises, smart-enterprises, etc.

People have been studying the nature of knowledge as a phenomenon for thousands of years; there are many definitions of knowledge, but, as stated in [1], the results are still very fuzzy. In the field of Knowledge Management (KM), knowledge of different types, for example, individual and organizational types, is defined by [2] through radically different generic concepts, for example, through the concept "understanding" and the concept "asset" correspondingly. Very narrow definitions of knowledge lead to greater entanglement of the picture as a whole [3]. Due to this, many aspects of all real work with DIK objects can contradict DIK definitions. For example, definitions may ignore the reverse transformation of knowledge into information or information into data. When solving particular problems, some authors try to circumvent such collisions, in particular, using an indefinite meaning "information and knowledge" instead of one adequate term [4]. Guerino [5] also sees the randomness and ambiguity of the situation in the statements that the application of information and communication technologies (ICT) includes work with knowledge. In contrast, in [5] it is argued that ICT always execute only data processing (DP).

Against this backdrop, the study [6], in which the three-object scheme "Data> Information> Knowledge" and its properties are considered explicitly is meaningful. However, in [6], the valuable properties of this scheme are also distorted by narrow and specific interpretations. For example, information and knowledge are described through the properties of integratedness and compactness, which are not mandatory, transformation of knowledge into information and data is not considered, interpretation of the concepts of information and meaning is compromised by the given example of extracting information from data.

The author of this work has developed methods for solving various KM tasks. They were associated with the representation of knowledge for cognitive skills [7], with obtaining synergies through the integration of heterogeneous knowledge [8], with the organization of knowledge to support the participation of workers in the development of enterprise knowledge [9]. These tasks also manifested features of working with a DIK triplet which are not well reflected in definitions and standards. As a result, the task considered in [9] required the explicit introduction of the working definitions "Enterprise Information" and "Enterprise Knowledge" (they were formed by the specialization of definitions from [10]). Due to this, in [9] it was possible to constructively use the logical and causal connections between the data, information, and knowledge of the enterprise embedded in these working definitions. This experience confirmed the possibility of correctly and usefully determining the DIK triplet under the conditions of the existing chaos of definitions, and allowed us to avoid both unnecessarily narrow definitions and extremely critical evaluations, including some of those described in [5].

However, serious problems posed by unclear and inconsistent definitions of DIK still remain. They consist of shortcomings or loss of the logical foundation of complex multipurpose work, demanding correct separation of data processing procedures (including those done by ICT), acts of understanding the information presented by these data, and operations of creating, identifying and preserving knowledge as values

– both personal and enterprise's. Problems are amplified by the dynamics of constant changes in knowledge and requirements for their preservation and distribution in alienated forms [9] and by the need to control the resulting loss of information and knowledge due to their distortions and degradation (in saying this the author strongly disagrees with the opinion [1, p.15] about impossibility of knowledge degradation).

1.2 Goals and Objectives of the Study

Three years ago, the development perspective of several new international standards aimed at defining a large body of fundamental concepts and important terms in the field of ICT and KM, gave hope that the situation would improve significantly, in particular, using DIK to organize effective functioning of enterprises. However, this did not happen, which is reflected further in Section 3.

Nevertheless, the author assesses the situation not only as a chaos of heterogeneous views, but also as the presence of a large number of sources of useful information from which it is possible to isolate such valuable fragments ("knowledge nuggets") that can be integrated into a harmonious methodology. International standards and other normative technical documents (NTDs) can be considered one of the most important categories of such sources. Such an assessment gives this study the meaning and the possibility of its pragmatic orientation.

The purpose of this study is to form a coherent system of definitions (SoD) for DIK concepts and to form, due to this, the correct conceptual foundation of complex projects covering the end-to-end data, information and knowledge management processes in modern enterprises. This system is further referred to as SoDDIK.

In view of this, the main objectives of the study include

1. determining the system of requirements for the desired SoDDIK;
2. selection of information sources from relevant NTDs;
3. evaluation of DIK definitions in selected NTD, selection of SoDDIK from them;
4. formulation of recommendations on the use of SoDDIK.

Later in this publication, Section 2 describes the research methodology, in particular, the requirements for SoDDIK. Sect. 3 presents the results of the selection and analysis of the original NTDs, describes the fixation and commenting of the generated SoDDIK. Sect. 4 discusses how to use SoDDIK; Sect. 5 summarizes the research, discusses changes in interpretations of the fundamental concepts under consideration, and suggests a hypothesis about the reasons for these changes.

2 Research Methodology

2.1 Foundations of the Methodology

In the basis of the methodology there are the following fundamental approaches:

- a historical approach applied to general interpretations of the DIK and for evaluating the selected NTDs and their definitions of the DIK in the context of specific historical periods;
- a combination of positivism and empiricism for understanding ways of assessing the truth of knowledge, as well as their balance with postmodernism approaches [11, p. 480], in particular, when determining the actors of semiosis;
- systems thinking for achieving the integrity and focus of the formed system SoDDIK.

According to the author of this publication, the growth of the diversity of DIK definitions will continue for a considerable time, aided by the dissemination of the views of postmodernism [11, 12]. Therefore, at this time there is no reason to expect the appearance of a new and, at the same time, generally accepted version of these definitions, which constitute a harmonious triplet. It is rational to conduct a search for a set of compatible definitions of each of the DIK concepts in basic documents defining activity norms in various aspects of the Enterprise Engineering (EE) complex discipline. International standards for their intended purpose are introduced as such documents. They also provide a DIK link to a wide variety of related standardized concepts and recommendations in the areas of DP, KM, and a number of related ones.

The problems presented in Sect. 1 show unfitness of work with each DIK concept isolated from the rest ones. It is required to take into account the connections of each of these three concepts with the other two and with the most important adjacent ones, to choose definitions taking into account their connections with processes in the fields of processing and transmitting data, information, and knowledge. Some of these connections are illustrated by Fig. 1, which will also be discussed in Subsect. 4.3, when discussing the results of the study.

2.2 System of Requirements for SoDDIK

The methodology includes the following requirements for SoDDIK.

REQ1. Definitions of a DIK triplet should reflect the following set of fundamental provisions and models related to practical areas of work with the DIK:

- the models of the “semantic triangle of Orgen-Richards” [13] and the “semantic tetrahedron of Pavlov” [14, p. 71] with the support of the conception of continuously ongoing semiosis;
- relevant principles of postmodernism [11, p. 480] and second-order cybernetics rules [15];
- provisions of the impact of the internal context of the person-actor, including his values attitudes not only on understanding something, but also on the result of its perception and recognition preceding understanding (see the reference to the example of visual perception given in [16, p. 8]);
- a combination (but not a merger) of data presentation that is hypothetically valuable for work, on the one hand, with their perception and understanding as information and use as knowledge, on the other hand;

— accepting as a basis for the definition of information its approximate interpretation as recognition of signs recognized by the recipient as an abstract (hypothetically) meaningful message, but not necessarily representing true and / or verified information (also applies to the presentation of experience);
— accepting as a basis for the definition of knowledge its approximate interpretation in the style of "a justified true belief" with regard to some information, taking into account the probabilistic nature of its truth, the fundamental incompleteness of its verification, subjectivity and situational nature of the subject's conviction in understanding and recognizing this information.

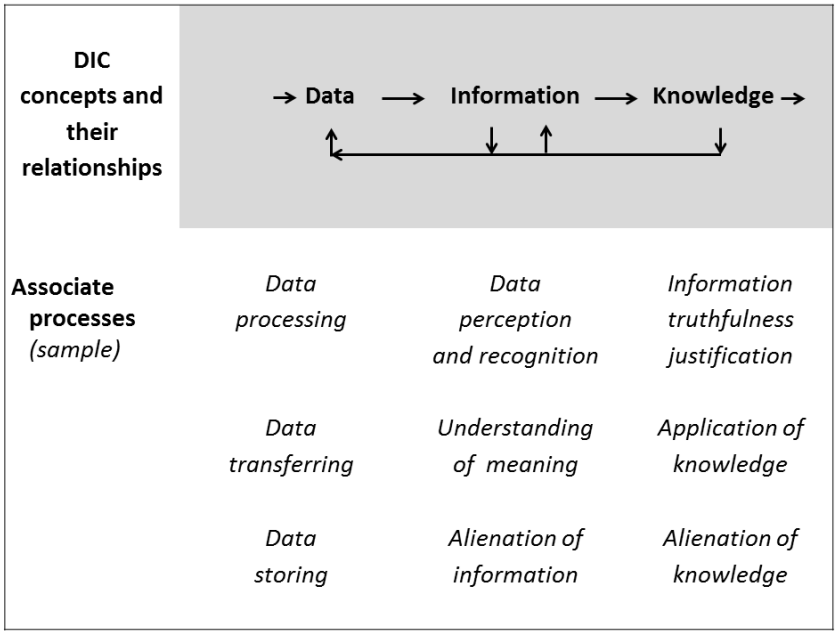

Fig. 1. The outline of the necessary connections between the DIK concepts and an example of the processes associated with these connections.

REQ2. Definitions in SoDDIK should support some functional causal relationships [17] between the defined concepts from the DIK and the concepts used in the definition. Such relationships may be causal relationships of one DIK concept with other concepts from SoDDIK, as well as with concepts that are not included in DIK. It is desirable that they indicate the presence of a method or procedure for obtaining an object of one DIK concept based on the use of other objects, primarily those included in DIK.

REQ3. DIK definitions for checking them for compliance with the requirements of the methodology are selected from the definitions contained in NTDs. This means that attempts to re-create anew the definition and understanding of the DIK are not allowed. International standards, due to the methods of their development, in common case are representing mature knowledge; this is also valid in the areas of working with DIK objects.

REQ4. SoDDIK is intended for use primarily in the field of EE and enterprise functioning. Therefore, the definitions in SoDDIK should be correctly docked or potentially harmonized with most of the definitions of other concepts that are practically used in EE, and the definitions in SoDDIK can also be complemented by popular metaphorical descriptions of these concepts.

2.3 Other Bases and Components of the Methodology

As a research tool, the semantic network apparatus was used to analyze the structural logic and semantics of DIK definitions. Regarding the requirements for semantic properties of information, Norbert Wiener's provisions of the properties of information [18], refined by their interpretation by Umberto Eco in [19], as well as the provisions of second-order cybernetics [15] in relation to human communications were taken into account. The requirements of the analysis of semantics of figurative texts also include the principles of unlimited semiosis and potentially unlimited polysemy of messages [19] and the provisions of the inevitability of distortions of meaning in communications [20].

3 The Research Results

3.1 Source NTDs

The initial long list of NTDs was checked for the presence of DIK definitions, and the first correlation of these definitions with the criteria of the methodology was carried out. On this basis, the NTDs list was shortened and divided into two groups. In the first one, named the main group, standards explicitly designed to define and interpret the target and related concepts and containing them are left. The second group was defined as an additional one to exclude isolation of the research with only one closed group of sources.

The main group of NTDs (standards). It contains:

- the first international standard in the field of KM [21];
- the basic and one of the most recognized standards in the field of management [22];
- the standard glossary, combining the terminology of international organizations and associations in the field of ICT [23];
- authoritative standard glossaries lasting more than 25 years in the areas of Software Engineering (SWE) and DP [24, 25], reflecting the classical approaches to data and information in the field of ICT.

Additional group of NTDs. It includes:

- ICT management standards, in particular, [26] - a basic standard in the field of systems engineering, [27] - a standard for measuring the maturity of processes, [28] - a variant of the international standard for information security, adopted as

the national standard of Russia, and a number of others, including those in the field of risk management;
- Bodies Of Knowledge in the areas of business analysis, business architecture, and systems engineering, in particular - [29, 30];
- Internet resources, first of all SEVOCAB (https://pascal.computer.org) as a promptly updated collection of terms from different standards for SWE and DP fields, and the popular resource www.businessdictionary.com which affects the practice of the use of terms in the business enterprise environment.

3.2 NTDs Analysis Results. Definitions Included in SoDDIK

NTDs analysis of the main group. The Table 1 shows the NTDs of the main group and the DIK definitions selected from them that best satisfy the methodology.

Table 1. The definitions for SoDDIK and other results of NTDs analysis.

NTD: Year, area, reference number	**Definition for Data** (#) – definition number for the concept in the standard	**Definition for Information**	**Definition for Knowledge**
1990; SW Engineering [24]	**For SoDDIK:** (1) "A **representation** of facts, concepts, instructions in a manner suitable for communication, interpretation, or processing by humans or by automatic means " (see Note 1)	is absent	is absent
1990; Data Management [25]	(2) = Copy of (1) in [24] (see Note 2)	**For SoDDIK: "The meaning** that humans assign to data by means of known conventions that are applied to the data" (see Note 3)	is absent
2015; Quality management [22]	Essential defects (see Note 4).	**"**Meaningful data", which is close to copy of [25] (see Note 5)	**For SoDDIK: "**Available collection of **information being a justified** belief and having a high certainty to be true" (see Note 6)
2017; SSE Vocabulary [23]	(1) = Copy of (1) in [24] (see Note 2)	Essential defects (see Note7);	Essential defects; unacceptable. (see Note 8)
2018; Knowledge management [21]	is absent	Copy of [22] (see Note 5)	Essential defects, but can serve as a note. (see Note 9)

The mark “For SoDDIK” shows the three definitions that most fully satisfy the principles and possibilities of SoDDIK. They are selected from the standards: for data, the first definition given for data in [24] is selected, information definition is taken from [25], knowledge definition is taken from [22]. Acceptable as brief or complementary metaphoric versions of the definitions from other standards, as well as the use of copies of the selected definitions of the main NTD group, are also shown.

Comments: *Note 1* - *Note 9* are given for the different cells of the Table 1 and are referenced by the cells. They explain the reasons for the different assessments of definitions, both chosen and rejected.

Note 1: A definition indicates a causal relationship that determines the occurrence of data by presenting something in a specified manner. It corresponds to the semantic models [13, 14]. Here the symbols "(1)" indicate that the first definition from the several ones is quoted.

Note 2: Such a link indicates that the definition indicated by the number is borrowed from the standard marked by the reference.

Note 3: The specified meaning is the mental meaning (sense) of the data, as opposed to the meaning as the object (referent) from the real world represented by the data, which corresponds to the semantic models [13,14]. The definition indicates a causal relationship that determines the occurrence of information by giving the meaning to the data by a person.

Note 4: “Essential defects”: data are defined by their identity with facts about objects, although facts exist independently of data.

Note 5: The specified variant is evaluated as a simplification, which can be used in working order as a shortened version, but without a loss of meaning of a more complete definition. For this, a full definition must be applied in SoDDIK.

Note 6: It is a sound variant of interpretation chosen in the methodology as a reference one. A causal relationship is specified that determines the emergence of knowledge through the verification of conviction and validity. Values (usefulness) as a property of knowledge that is essential in EE tasks can be complemented using a note, for example, as stated in the Note 9.

Note 7: “Essential defects”: information is determined through knowledge with very special properties. The meaning of the definition in this NTD is given only in a note, and what is stated in this note, does not correspond to the definition.

Note 8: “Essential defects”: knowledge is defined as a concept related specifically to the IDEF1 modeling environment.

Note 9: “Essential defects”: the definition is a metaphorical description, as analysed and discussed in [1]. The definition is not formally related to information or data; as a result, the definition means not only knowledge (for example, it can mean medications that stimulate brain activity). For applying in EE, this description can be used as a note to the main definition to highlight the value aspect of knowledge objects as assets of an enterprise.

Comments on some other NTDs. The definitions of other NTDs from the reviewed sources are not used in the SoDDIK for reasons similar to those indicated in the notes to the Table 1 as “Essential defects”, ”or due to the lack of the required definitions in the glossaries of these NTDs.

4 Discussion on the Use of SoDDIK

4.1 Basic Applications of Formed SoDDIK

The main application of SoDDIK is using it in complex projects and enterprise processes which include both IT components and knowledge-based business procedures. In particular, this includes projects for creating and applying KM systems using ICT components. Depending on the specifics of the enterprise, the basic definitions of SoDDIK can be supplemented with one or another set of metaphorical definitions, for example, from those reviewed in [1].

When using SoDDIK, it is also useful to use derivatives that are compatible with the selected definitions of DIK and related terms of the main group of NTDs, in particular, the following: document, (1) documentation, semantics – from [24], data medium, data carrier – from [25], object, see also Note 4 for the Table 1 – from [22], context, data processing, (2) semantics – from [23]. This applying supports the effectiveness of the joint use of these basic standards in complex enterprise projects, including works in the areas of DP, SWE, Quality Management (QM) and KM, which differ significantly from each other.

4.2 Capabilities of SoDDIK to Support Dynamic Business Processes and Expertise

For modern enterprises, it is important to quickly and efficiently organize network business processes and the work of multi-professional groups, for which special efforts are needed in the field of KM [9]. SoDDIK promotes effective interprofessional application of general and adjacent knowledge in the context of high dynamics of processes and the complexity of work.

SoDDIK and the methodology for its formation can also be applied to assess the correctness and usefulness of concepts and derivative terms introduced into strategic conceptual documents of a wide variety of initiatives of any scale.

4.3 Support of Reverse Conversions between DIK Objects

Fig. 1 shows not only direct causal connections from data to information and from information to knowledge, but also connections in the opposite direction. These reverse links represent transformations and transfers that are performed when codifying and alienating knowledge and information, when they are transferred for storage or for perception by other persons / actors. These transformations correspond to the principles of continuously ongoing and unlimited semiosis included in the research methodology.

Knowledge transformed by codification procedures and placed in repositories often continues to be called knowledge. However, SoDDIK shows that when alienating, codified knowledge is stored in the data state, which is quite consistent with the statement in [5]: ICT processes data, but not knowledge.

Saved codified knowledge records can be considered as enterprise knowledge again at the future stages of life of an enterprise only if

- in this future, an interpreter (recipient) who knows the language of codification will be found,
- the recorded messages will remain true, as well as
- the interpreter's conviction in their truth and their value for using as a valuable asset of the enterprise will persist.

At the same time, there is a reason to consider such records not only "just data". The preceding understanding of the original message and the assessment of its value properties for an enterprise distinguish this secondary data from the original (primary) ones that did not undergo these phases of processing. For this reason, for such secondary data it is justified to obtain the name "Model of alienated knowledge of the enterprise", which will distinguish them from both raw data and knowledge as such.

The same is true for the codification and preservation of information.

Work with alienated knowledge as with data representing the model of this alienated knowledge, highlighted by clear definitions, allows us to more constructively detect cases of natural (for example, forgetting, unintentional distortion) or an intentional (false news, fakes) decrease and even disappearance of knowledge. This approach allows developing support for the quality management of alienated knowledge by means of ICT and not only, as well as planning activities to ensure the information security of people and enterprises in the modern formulation of this task.

5 Conclusion

5.1 DIK Definition System as a Conceptual Core of Multi-professional / Multidisciplinary Projects, Systems, and Enterprises

In the definitions and interpretations of the DIK concepts - data, information and knowledge, there is a recognized chaos. Under these conditions, for the professional area of EE in this study, it was possible to elicit a set of constructive and compatible standardized definitions of these three fundamental concepts that serve as central terms in almost any activity. This applies in particular to the activities of enterprises that use constantly updated knowledge.

International standards in the areas of Data Processing, Software Engineering, Quality Management, Knowledge Management were the sources of definitions. The possibility of supplementing the DIK with standardized derivative concepts and terms is shown. The constructive nature of the definitions is ensured by the presence of functional causal relationships in the definitions of the concepts being defined. As a result, the DIK triplet acquires the character of the DIK definition system (SoDDIK), and the objects behind the concepts can be connected at enterprises by well-defined procedural links. Such an approach allows, on the basis of SoDDIK, to jointly apply standards for the above-mentioned different professional areas with reducing interprofessional barriers in modern enterprise development projects.

The methods of direct application of the generated SoDDIK, as well as the organization of reverse processes of working with knowledge, information, and data, including the reverse conversion processes from knowledge to information and to data, are shown.

5.2 About "Blurring Effect" by Postmodernism and the Perspectives

In Subsect 3.2, in the Table 1, the standards are ranged from those that contributed the most to SoDDIK to those that contributed the least. It can be seen that this order coincided with the order of their positioning from the NTDs with the greatest age to the newest. This cannot be considered final evidence of some effect, but, in the author's opinion, is not a random coincidence. It is not by accident that the NTD [24] for the chosen definition of the term "data" has remained a source widely quoted in new generations and versions of the ISO and IEEE standards since 1990.

This shows that the sustainability of DIK definitions, in particular, those that penetrated into standards over the last 7-8 years, has reduced. As a hypothesis, the author proposes a thesis that this reducing is caused by the strong impact of postmodernism dissemination in the ICT and KM fields. This dissemination causes blurring of basic concepts coherence and sustainability of their interrelations. Nevertheless, this study showed that there are normative triplet DIK definitions having full enough coherence and sustainability. The author considers the EE discipline one of areas where the triplet DIK definitions can be meaningfully used. The rationale of the author's conviction stems from the conclusion in [31] that the EE development paradigm can to progress in the form of a continuously extension, rather than in the form of a revolutionary breakage. This ensures the perspectives of meaningful DIK triplet application in EE field on a historically visible horizon.

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