"Made *with* Knowledge"
Disentangling the IT Knowledge Artifact by a Qualitative Literature Review

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Keywords: Knowledge Artifact, IT Artifact, Organizational Knowledge, Literature Review.

Abstract: Knowledge Artifact (KA) is an analytical construct by which analysts, researchers and designers from different disciplines usually denote those material objects that in organizations regard the creation, use, sharing and representation of knowledge. This paper aims to fill a gap in the existing literature by providing a conceptual framework for the interpretation of the heterogeneous contributions on this concept in the specialist literature. From our survey of the main contributions to the definition of this concept, we outline a spectrum of stances laying between two theoretical extremes: we denote one pole "representational", as it is grounded on the idea that knowledge can be an "object per se"; and the other pole "socially situated", as it builds on the viewpoint seeing knowledge as a social practice, that is an epiphenomenon of a situated, context-dependent and performative interaction of human actors through and with "objects of knowing". In proposing a unifying model to gather complementary dimensions of knowledge together, our aim is to shed light on the multiple ways these ideas can inform the "reification" of knowledge into particular IT artifacts, which we call IT Knowledge Artifact (ITKA), and on how seemingly irreconcilable positions can contribute in the design of these computational artifact supporting knowledge work in organizations.

1 INTRODUCTION

"IT artifact" is a general expression to denote "the application of IT to enable or support some task(s) embedded within a structure(s) that itself is embedded within a context(s)." (Benbasat and Zmud, 2003). Convincingly introduced in the Information Systems literature almost 15 years ago by Orlikowski & Iacono, such a concept has been addressed by hundreds of scholars in this time lapse from different and complementary perspectives (Akhlaghpour et al., 2013) and endowed with several definitions (Alter, 2006) to account for the multiple manifestations and proteiform nature of software applications in organizational settings. Notwithstanding this apparent scholarly variety, recent contributions are converging towards a stronger recognition of the importance of both the semiotic and social nature of the IT artifact (Lee et al., 2013), as this is never "natural, neutral, universal, or given [but it is rather] *socially created,* […] shaped by the interests, values, and assumptions of a wide variety of communities of developers, investors, users, […] *embedded* in […] a *social contexts* [that let][…] *emerge* [them] from ongoing *social practices,* […][and] not static and unchanging, but in a *continual evolution.*" (Goldkuhl, 2013). In particular, it has also been recently claimed that taking the socio-technical nature of the IT artifact seriously (Markus and Mentzel, 2014; Harrison et al., 2007) is essential to promote "ethical responsibility [and] to minimize the negative consequences of information and communication technologies". In this paper, we focus on Socio-technical IT artifacts that support knowledge, as a valuable subset of the more genera concept discussed above, and hence on the notion of IT Knowledge Artifact (ITKA in what follows). In (Cabitza et al., 2014) this class of software applications has been proposed to encompass "material [IT] artifacts [which are] either designed or purposely used to enable and support knowledge-related processes within a community, […], like idea expression and exchange, content and structure negotiation, meaning reconciliation, collective deliberation, new product and process co-design, knowledge representation at various degrees of

Cabitza F. and Locoro A..
"Made with Knowledge" - Disentangling the IT Knowledge Artifact by a Qualitative Literature Review.
DOI: 10.5220/0005086100640075
In *Proceedings of the International Conference on Knowledge Management and Information Sharing* (KMIS-2014), pages 64-75
ISBN: 978-989-758-050-5

(under)specification, problem framing and solving, mutual learning, and novice training".

Tackling this matter from a socio-technical perspective requires focusing on those IT artifacts that create and circulate new information within human practices, often on the basis of computational rules that in some way mirror domain-specific knowledge, as well as on those artifacts that enable and support knowledge-intensive activities and tasks both at human (i.e., cognitive) level and at social (i.e., community) level. A first step in this direction is to focus on the different aspects of computational support to knowledge practices, as emerging from different research strands and scholarly works articulated around the concept of Knowledge Artifact (KA in what follows).

We believe it is time to denote these particular ITKAs in more precise and specific terms (starting from the work of Cabitza, 2013), in order to fill a gap in the literature on them where, to the best of our knowledge, a review drawing on affinities and divergences in the use of the term KA is still missing.

The purpose of this work is then to conduct a qualitative review that would help answer some main research questions like: "what do we talk about when we talk about knowledge" as in (Davenport and Prusak, 2000) in the IT discourse? What are the underlying assumptions in the design of ITKAs? How these assumptions affect the design of these artifacts and, consequently, their low or high adoption and effective use by their intended users?

The phrase mentioned in the title of this contribution epitomizes in an intentionally ambiguous manner the two extremes of whole spectrum of possible answers that can be given to the questions above mentioned; a bipole where ITKAs can be seen as either "made *of* knowledge" (Salazar-Torres et al., 2008) or "made *in virtue of* knowledge" (Brown and Duguid, 2001). On one pole, we can recognize the tenets of the Knowledge Representation (KR) field, which assumes a realistic perspective on knowledge, i.e., a relation between the objects conceived in the mind and the apparently immutable outside forms perceived as reality. KR expresses the concrete possibility to represent things, in order to capture their essence for sharing a discourse with others. This pole roots in Artificial Intelligence and is based on some principles (Sowa, 2000) that inform the design of ITKAs as KR devices: this includes models of real objects according to a formal theory that elucidate their nature, their relations, and their instances. Knowledge, in this sense, should represent the reached consensus by a community on a description of a piece of reality, being that a domain of discourse, an application, a task, and so on, which has been disambiguated, automated and embedded in a system for managing knowledge.

On the other pole, a complementary mode of knowledge, or better yet of "knowing", draws on the distinction between the procedural "know how" and the discursive "know that" (Collins and Evans, 2008), but also on a dimension of interpretation, where "an individual pre-understanding is a result of experience within a tradition" (Winograd and Flores, 1987, p. 74). This knowledge disposition is a part of a process that is "neither subjective nor objective" (Winograd and Flores, 1987, p. 75) and has biological roots (Maturana and Varela, 1992): it emerges from patterns of interaction that couple living organisms with their internal structures and external environments, and orient their actions and changes "in many dimensions at the same time" (p. 116). (Greenhalgh and Wieringa, 2011) grasp such interplay of knowledge with the word "mindlines", that is "internalized guidelines"; in other words, the capacity of "continually being adjusted partly by grazing on written sources […][and] mainly by reflecting on experience during discussion with colleagues and opinion leaders, […][especially when they share] real stories of how they managed real cases" (p. 506).

The main contribution of our work is the proposal of a conceptual framework of key values and attributes for the analysis of the rationales and design principles at stake around the concept of (IT)KA (that is simply the computational counterpart of a KA), according to the results of an extensive qualitative review. The outcome of this analysis helped us conceive two main categories of ITKAs: the "Representational ITKA" and the "Socially situated ITKA". In general, this categorization could be a tool for the analyst and designer to interpret the peculiarities of the setting hosting ITKAs, as well as to understand the ways and goals according to which ITKAs are built and used. In addition, this analysis could be a first contribution to unravel implicit values and assumptions for ITKAs design.

The paper is structured as follows: after a brief introduction to the method adopted for our qualitative review, we show the results of the different phases of our analysis, discuss them by also providing examples of design, and conclude.

2 METHOD, CATEGORIES AND DIMENSIONS OF ANALYSIS

2.1 Search and Selection

Our review of the literature on ITKAs relies on the works of (Webster and Watson, 2002), and (Wolfswinkel et al., 2011). We strictly adhere to all the phases listed and described in the last paper, whose analysis phase corresponds to grounded theory methodology. The search and selection phases are depicted in Figure 1. In particular, for the retrieval of relevant articles on KAs the Google Scholar engine was queried in Summer 2013, with the following keywords: "Knowledge Art*fact* is|are|(can be)", for the first round of searches. The top ranked articles with their abstract were examined, and we proceeded with a selection of the part of them that resulted within the scope of the review as formulated in the introduction. This resulted in a final selection of 21 sources, each containing a definition of KA, and part of which were used in our design Section. A second and a third query were issued with the term: "knowledge representation", and "ontology design", respectively, in order to refine the branch of the KAs literature on the representational side. A total of 40 papers were selected, and 3 papers were kept as paradigmatic of KAs real applications. A fourth query with the term: "epistemic object" was finally issued in order to refine the branch of the KAs literature on the situativity side. A total of 3 papers were selected and used as above. A final round of queries were issued in the AIS eLibrary for finding selected theoretical, primary study, and review articles based on the criteria of having being published as a journal article (e.g. MIS Quarterly Executive) or conference proceedings (e.g. ICIS and ECIS) of the AIS community. After a thorough analysis and re-read of excerpts, a final bunch of 15 articles was finally selected and exploited for the creation of our conceptual model on KAs. This selected literature spans at the intersection of theoretical approaches to organizational knowledge (Burrell and Morgan, 1994), sociological and information systems studies on IT conceptualization (de Vaujany, 2005; Iivari et al., 1998; Iivari, 2007; Orlikowski and Iacono, 2001), as well as Knowledge Management Systems reviews and Organizational Knowledge resources studies (Holsapple and Joshi, 2001; Alavi and Leidner, 2001, Binney, 2001, Rodríguez-Elias et al., 2008).

2.2 Analysis and Presentation

The open coding phase was conducted on either the 21 papers containing definitions of KAs (see Table 1 for a detail of sources and definitions), and the 15 theoretical papers on IT artifact and Knowledge Management conceptualizations; the axial coding phase was conducted by extracting conceptual dimensions from the 15 theoretical papers (the findings of the articles were put in an output table, as in Webster et al. 2002, with the categories of the research conceptualization as concepts. Each article could span more than one concept and attribute. See Table 2), and by classifying the 21 papers on KAs definitions and the 10 real case applications papers according to them (see the descriptive analysis of Sections 3.1 and 3.2); the selection coding phase lead to a further synthesis of our findings into the two main categories of KAs classification, and was based on all the papers collected (see Figure 2 for a summary of our findings).

2.2.1 Open Coding: Ka Definitions

Table 1 reports the 21 definitions of KA and can be ideally split in two quite equal parts. The first part refers to a definition of KA where knowledge is conceived as being a part of *res extensa,* to look through this definitorial phenomenon from a Cartesian perspective. The second part of definitions puts more emphasis on the communicative aspects of individual activities, whose collectively shared and interpretable output is the piece of knowledge (here conceived as a part of *res cogitans*) that can be supported by KAs. This ontological distinction brings important consequences in the way KAs are designed for the aims and scope that they should support, with their different forms and within different environments.

2.2.2 Axial Coding: Categories and Dimensions of Knowledge Artifacts and IT Design

The two dimensions of objectivity and situativity (our input dimensions for classifying ITKA-based applications, see Section 2.2.3) characterize the categories of our output map, depicted in Table 2, where a bipolar conceptualization of the literature on KAs has been conceived. This table is a classificatory device for our review activity. The dimensions described are ideally split in two parts.

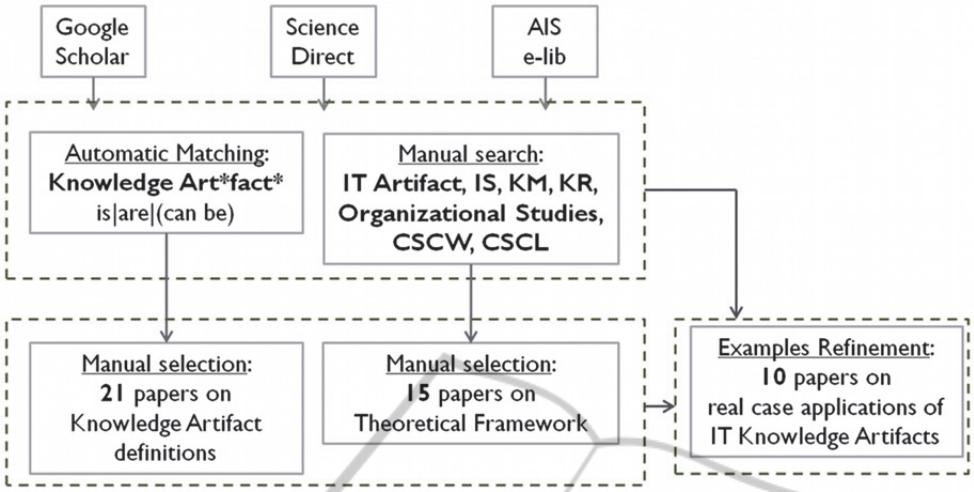

Figure 1: Search and Selection steps.

The first part is theoretical and stems from the framework of Burell & Morgan, within organizational studies. We enrich the ontological dimension of knowledge with other perspectives: that of Nonaka & Takeuchi talking of explicit and implicit knowledge; that of Sowa indicating the way knowledge is representable; that of Duguid highlighting the cultural side of knowledge, especially in Communities of Practice.

Besides Burrell and Morgan epistemology, we have preferred to contrast the term "positivist" with a set of terms that should better characterize the "non-positivist" stance. To this aim, we especially highlighted a historical that sees users and systems as an evolution towards "interactive agents" from passive ones. This, in our view, better expresses the epistemology of the "Socially situated KA" perspective.

The "knowledge modes and structures" are those of Alavi & Leidner, Iivari and de Vaujany. Rodríguez-Elias et al. and spans from the more "unstructured" (as in audio, video and free text) to the more "structured" (as in metadata, formal categories and graphics).

The second part of Table 2 focuses on the application of the first part principles to IT artifacts design and requirements. Orlikowski & Iacono and Iivari gave a classification of IT artifacts and of IT applications archetypes, respectively. We related and decided to group them under a unique perspective.

Alavi & Leidner gave a taxonomy of which kinds of knowledge is processable by KMS, and Holslappe & Joshi extracted some attributes of organizational knowledge resources. We selected from both the more salient for our conceptualization. We added Massey & Montoya-Weiss' conceptualization of time, and Iivary's IS development approaches classification, as well as March & Smith's evaluation dimension in IT. A final dimension is that of KM Applications by Binney, as a frame into which we could exemplify how the issues of passing from representational knowledge to socially situated knowledge may also fit into the given "KM landscapes".

2.2.3 Selective Coding: Objectivity Vs Situativity

The two categorical dimensions of objectivity and situativity, together with their relationships with different kind of IT applications, are reported in Figure 2.

Situativity, for our purposes, can be epitomized in terms of the extent the KA is capable to adapt itself to the context and situation at hand, as well as the extent it can be appropriated by its users and exploited in a given situation. Objectivity, to our aims, can be conversely considered the capability of the KA to represent true facts in an objective, crisp, and context-independent manner, as well as the extent it can be transferred among its users as an object carrying some knowledge with itself. To adopt evocative terms introduced by (Goguen, 1992) and (Latour, 1987), then objectivity refers to the extent a KA is "cold / immutable" (cf. Latour) and "dry" (cf. Goguen), while situativity refers to the extent such an object is "warm / mutable", and "wet", respectively.

Each group of applications of Figure 2 is associated with the research and design principles, values and assumptions of the disciplines that lay at the intersection points of the Figure. This schema

wants to express how much objectivity and situativity is implied by each design input and requirement for the IT artifact as the final output. Besides the two extremes, no other group of applications contains purely objectivity or situativity, but the most part of them result in a differently mixed blend of the two.

Depending on the attributes collected in our axial coding analysis (the dimensions depicted in the second part of Table 2), we can give a brief overview of what objectivity and situativity mean in terms of the knowledge phases, structures, attributes, and knowledge-based activities that these applications and tools are supporting, while delegating a detailed description of some aspects of their design to the next Section.

Objectivity seems to characterize more all those large-scale applications that are oriented to business and enterprise activities, where the dimensions of organizations require to handle information quantitatively, and in a centralized way (e.g. by collecting all the specialized knowledge distributed among the different sectors of an organization and by adopting a uniform and top-down codification). The aim of such applications is to collect, store, retrieve, and apply information across the lens of standard procedures that guarantee the control of a complex system and the rapid problem solving and decision making at a "routine" level, as well as at a managerial level.

Information systems technology lays in the middle, is scalable, and constitutes the set of tools able to process and manage information (i.e. to structure, store and maintain the documents by indexing, organizing, classifying, filtering it, and so on).

Computer Supported Cooperative Learning and Computer Supported Cooperative Work technologies support a more individual and personal dimension in the management of the knowledge that they are called to handle. In a way, the environments of such applications are less standardised, not totally specified, and strongly oriented to creation, design, innovation, apprenticeship, creative working and management, and unstructured communication and cooperation tasks (often outside and between organizations).

In what follows, a necessarily brief review of some literature on ITKAs is reported, as selected and framed along our conceptual categorization and analysis.

3 DISENTANGLING ASPECTS OF ITKA DESIGN

3.1 The Representational ITKAS

Representational ITKA are objects where knowledge is reduced to a formal logic way that aims to capture their "essence" (Holsapple and Joshi, 2001; 2002). In this tradition, KA may have varying degree of structuredness e.g.,(Giunchiglia and Chenu-Abente, 2009), from documents, diagrams, manuals, to formal ontologies and knowledge bases, passing through the whole range of semi structured sources that are used in organizational settings, like spreadsheets, forms, XML documents, and the like (Toro and Kulkarni, 2008; Diaz and Canals, 2007).

In addition, in this stance KA can be endowed with a varying degree of generativity, from simple proof checkers to even very complex inference engines. Ontologies (Guarino, 1998), for example, are the representational objects that epitomize knowledge structure and computation over it.

The ontological spectrum (Noy and Hafner, 1997) includes the so called lightweight ontologies, i.e., simple vocabularies of hierarchical terms, which mainly serve to classify items; lexical resources (Fellbaum, 1998), which makes explicit and expandable the local space of word meanings, for advanced search and retrieval tasks; fully axiomatized theories, all encoded in logic languages (Baader, 2003) and equipped with reasoning tools.

As the computational complexity tends to increase rapidly, more than often the model of reality that undergoes the conceptualization and axiomatization process tends to be partial and oversimplified (Sowa, 2000).

According to the above definitions, representational KA are those stored in a Knowledge Management repository (Weber et al., 2006), in a Digital Library (Candela et al., 2008), and the like, as structured sources of static knowledge, as well as in more sophisticated tools that computationally "activate" knowledge, like Decision Support System or Expert Systems (Matook and Brown, 2008), or any semantically enriched IT System, with its automatic or semi-automatic services for structuring, storing, extracting, retrieving, evaluating, and maintaining knowledge artifacts e.g.,(Maedche et al., 2003).

Table 1: KA: 21 definitions. Italics in definitions is ours.

Author	KA definition
Paavola et al. (2004)	Knowledge creation activities rely heavily on the use, manipulation and evolution of shared KAs *externalizing a body of (tacit or explicit)* knowledge
Smith (2000)	any item that captures *explicit or tacit* knowledge
Ancori (2000)	something where knowledge is made *"explicit" and "recorded"*, as the *formal outcome of a process* of codification
Seiner (2001)	defined piece of *recorded knowledge* that exists in a format that can be retrieved to be used by others
Diaz & Canals (2007)	minimal *unit of explicit and exchangeable* knowledge something that encapsulates knowledge [that can be] *informal* (where knowledge is strong hard-coded), *semi-formal* (where informal knowledge representation is mixed with formal representation), or *formal* (where knowledge is represented by a formal knowledge representation system)
Krupansky (2006)	an artefact which represents an *encoding* of knowledge
S. Gandhi (2004)	When knowledge is *fixed or codified*, a KA is created, and it is this knowledge artifact that can be *managed*.
Holsapple & Joshi (2001)	object that *convey or hold usable representations* of knowledge
Holsapple & Joshi (2002)	object that *represents* knowledge
Weber et al. (2006)	whatever element stored in a KM repository
Weber & Gunawardena (2008)	a knowledge engineering *formalism of knowledge representation* […] that allows a computational system to make decisions and solve problems
Alavi & Leidner (2001)	must include the *minimal elements* for a user *to make a decision to solve a problem*, and be easily interpretable
Salazar-Torres et al. (2008)	*vehicle* for knowledge sharing artifact *made* of knowledge. [...] can be very useful to ensure the effectiveness of the *transfer and utilization* of knowledge in organizations of all sorts.
Mödritscher & Hoffmann (2007)	any piece of (digital) information *relevant for a certain working context and enriched with semantic information* in terms of metadata
Mangisengi & Essmayr (2002)	anything that allows knowledge to be communicated *independently of its holder*
Scrivener (2002)	artefact designed with the *intention of communicating* knowledge
Mansingh et al. (2009)	*input to and product of* knowledge enabled activities
Giunchiglia & Chenu-Abente (2009)	object created as a *result of an activity* which *encodes* knowledge, the *understanding or awareness* gained *beyond data*
Bereiter (2002)	*products or objects of thinking and reasoning* that can be *collectively* argued
Oinas-Kukkonen (2004)	serve as a *collaboration vehicle through interaction* between information producers and consumers, within a team of co-workers or among other stakeholders [and] *support understanding and communication in the individual learning* of new things
Y. Tzitzikas et al. (2007)	KA refer to *what is being created and/or shared by a group of learners* (and could be a set of words, documents, concept maps, ontologies, annotations, etc).

Table 2. Conceptual Framework of Organizational KM and ITKAs Design.

Attributes underlying assumptions for Design	Representational ITKA	Socially situated ITKA
Paradigms of study [Burrell & Morgan 1994]	Functionalist	Interpretive
Ontology (nature of knowledge) [Sowa 2000; Duguid 2005; Burrell & Morgan 1994; Nonaka & Takeuchi 1995]	explicit / representable (realism)	tacit / cultural / practical /actionable (nominalism)
Epistemology (interpretation of knowledge) [Burrell & Morgan 1994; de Vaujany 2005; Greenhalgh & Wieringa 2011]	positivist (nomothetic)	constructivist / interactionist /emergentist (ideographic)
IS approaches to IT conceptualizations (status of knowledge) [de Vaujany 2005]	autonomous passive (deterministic)	integrative (action and structure cannot be separated) malleable actively and interactively usable (voluntaristic)
Modes and structures of knowledge [Iivari 2007; de Vaujany 2005; Alavi & Leidner 2001; Duguid 2005, Rodríguez-Elias et al. 2008]	Explicit structuredl codifiable descriptive procedural objective essential formal rational / conceptual	Explicit unstructured interpreted socially constructed instrumental performed comprehensive subjective flexible / conventional
IT artifact archetypes (scope and aim of knowledge) [Iivari 2007]	To informate / to automate	To mediate / to augment
IT artifact views (activities based on knowledge) [Orlikowski & Iacono 2001]	Computational (algorithm, model), labor substitution, production and information processing tool	Social relation tool proxy / ensemble view
Knowledge Management views (phases of knowledge) [Alavi & Leidner 2001]	factual data oriented object to be stored and manipulated condition of access to information	personalized information state of knowing and understanding process of applying expertise potential to influence action
Attributes of knowledge in Organizational knowledge resources [Iivari et al 1998; Holsapple & Joshi 2001; Massey & Montoya-Weiss 2006; March & Smith 1995]	Quality: validity Main view: objective Time: discrete, ordered, dependent Level of certainty/detail: decidable / specified Usage: computational / procedural / top-down oriented	Quality: utility (means-end oriented) Main view: subjective Time: continuous, chaotic, independent Level of certainty/detail: undecidable / left incomplete Usage: pragmatic / situational / bottom-up oriented
Knowledge Management Applications [Binney 2001]	Transactional Analytical Asset	Process Developmental Innovation and creation

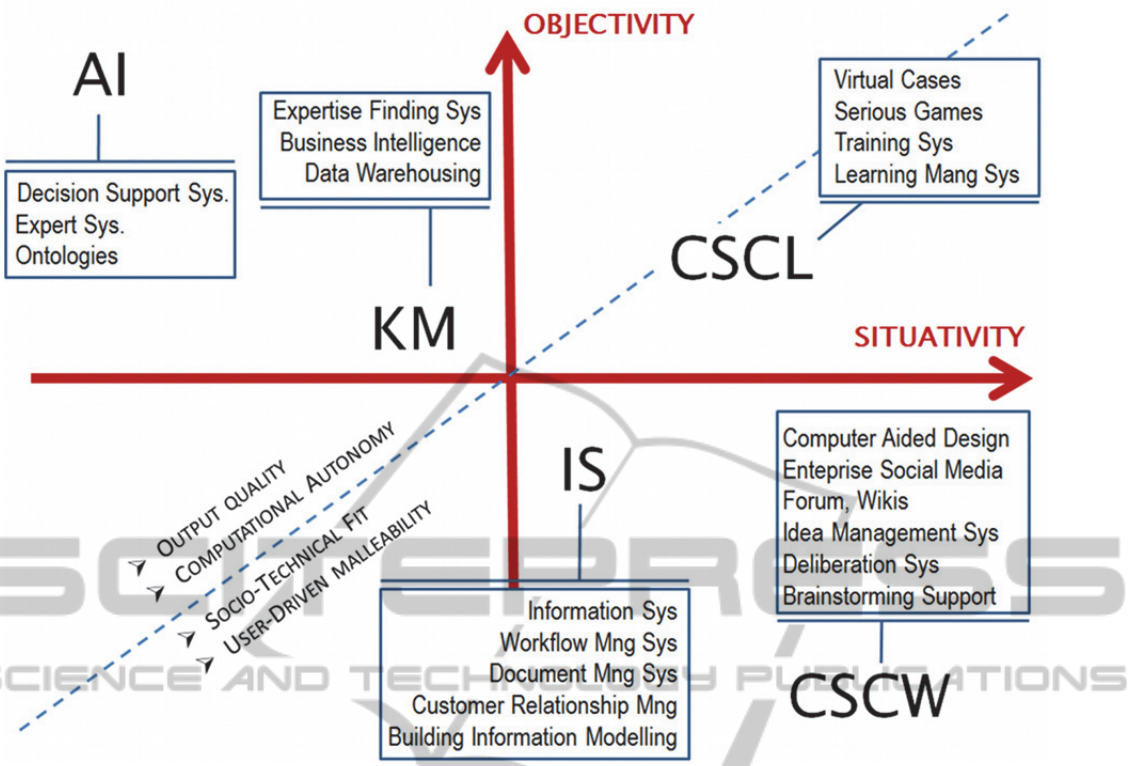

Figure 2: Selective Coding: classification of ITKA-based applications grouped by research discipline and according to the two dimensions of objectivity and situativity.

In a representational approach, some suggestions on how to couple formalisms with design requirements for a better use of KAs are devised (Szulanski, 1996). (Weber and Gunawardena, 2008) also recognize that "the design of knowledge artifacts includes the processes where they are applicable". KAs for enhancing and supporting highly specialized tasks in communities of experts are those depicted in (Bandini and Manzoni, 2002; Bandini et al., 2003, Salazar-Torres et al., 2008), where formal knowledge is collected with keeping in mind, and applying, principles and methodologies that involve instances, practices, and values of specific communities and of their past knowledge. In particular, the KA conceived in this project is a case-based reasoning KA, in that it supports innovation management activities by incorporating the jargon of the technical experts for recording past experiences. A case-based reasoning mechanism for problem solving is then provided to facilitate collaboration within members of other teams.

The computational part is based on the explicit semantics added to the rather implicit system of meanings of language symbols, to provide a flexible layer of negotiation that can adhere to the new case that needs to be collaboratively examined based on the past ones. New combinations of the elements represented in the KA memory support are obtained by exploiting fuzzy logic rules as computational counterpart of the qualitative variables of the specific domain and case at hand.

3.2 The Socially Situated ITKAS

Practice oriented definitions refer to something that is made during a performance, in "knowing" (Cook and Brown, 1999), seen as a "social product [emerging from the] messy, contingent, and situated outcome or group activity." (Turnbull, 2000).

In this context, KAs are not supposed to store knowledge or to be designed to "engender knowing" (Scrivener, 2002). Better yet, a KA allows its users to make apt and proper decisions or create innovation, or solve problems, and overcome breakdowns. In this stance, it acts as a support or scaffold to the expression of knowledgeable behaviors. In complex organizational settings, KAs regards also how to organize memories, report best practices, outline ideal and effective methods (Cabitza and Simone, 2012), because such representations (either textual, diagrammatic or pictorial) trigger opportunities for socialization,

internalization and, by evocation and memory aid, knowledge retention and exploitation (i.e., knowledgeable behavior). As "centers of gravity for knowledge [KAs] concentrate it, make it tangible, instrumental, effective" (Allen, 2004, p. 62).

(Knorr-Cetina, 1999; 2001) introduced the concepts of "performing-with" and "being-in-relation-with" to distinguish the relation with "epistemic objects", the classical objects of study in scientific practice, which implies a relational attitude more than a performative one. These objects are "capable of unfold indefinitely" although "instantiated", as they are "simultaneously mutating" (cf. (Suchman, 2007), on the situated actions in the context of "heterogeneously enacted and intrinsically indefinite events"). An "unfolding ontology" suitable for describing them should be based on post-scriptive structures, which may include the "temporality" of things into which "epistemic objects […] tend to [constantly point to a possibly] unreachable real whole".

(Ewenstein and Whyte, 2007) extended this notion to visual forms, through which both designers and engineers should cooperate on a common ground. Visual forms are mutable forms that unfold "in time", as "they are not yet but might become in future iterations"; "in space, as standpoint-specific boundary objects". For their boundariness they are defined "trans-epistemic objects", i.e. "capable of traversing and permeating different epistemologies of design".

(Massey and Montoya-Weiss, 2006) investigate the process of knowledge conversion (KC), both in indirect KC (solitary work interacting with the artifact) and in direct KC (synchronization via communicative human-to-human activity). They propose a model of "personal perception of time", i.e., a one task or "monophasic" entity vs. a "polyphasic" entity or structure of events.

What is put in the foreground by these design studies are the mutable social and temporal dimensions of knowledge forms, which seem to suggest inescapable requirements for the design of KAs.

4 DISCUSSION AND CONCLUSIONS

The literature review we have outlined above has shed light on the manifold, and sometimes even divergent, perspectives that have so far emerged about the nature of what scholars have wanted to denote with the term Knowledge Artifact in the last 15 years. Our literature review unveils the characteristic of the concept of Knowledge Artifact to be a "boundary concept" (Löwy, 1990), that is something that allows "disparate proponents to appropriate it in consonance with the main aims and scopes of their fields". However, with our review we have also aimed to raise awareness of both the complementarity and tensions existing between different stances that can be positioned at some point within the objectivity vs. situativity spectrum. In short, this categorization is ultimately aimed at shedding light on the necessary recognition that designing for effective knowledge artifacts requires to address once again important questions on what we want human knowledge to be, and accept as possible yet temporary answers contributions coming from the whole symbolic-subsymbolic range of stances that have been very briefly outlined in this work.

All in all, one could rightly wonder how the categories proposed in this conceptual framework can be reflected in distinct design principles or, even, more specific requirements. We hint at these principles here in a very general manner for limitations of space. A coherently representational stance will require KAs to be able to: store more or less structured documents; possibly classify them on the basis of some domain ontology; and enable their retrieval according to queries, filters, topic models and user profiles of varying complexity. The KA could also be capable of storing usable representations of declarative (e.g., assertions and rules) and procedural (e.g., algorithms, process models) to assist users in knowledge work or give them support in decision making. An ideal KA is assessed in terms of the quality of its output (pertinency, accuracy, completeness, timeliness, etc.) and of its autonomy in providing such an output on the basis of the available information (e.g., inputs) within acceptable range of deviations from the gold standards posed with respect to the quality dimensions mentioned above. This means that the process leading to the right output should be aware of the context, including the user, but within the variability accepted and considered in the computational model formally. In Figure 2 these features characterize the upper Cartesian hemiplane depicted therein, where also the main systems that are usually more focused on a representational treatment of knowledge are listed.

On the other hand, the situated perspective would require to design KAs that do not necessarily represent knowledge per se, as said above, but that

rather promote knowledge-related processes like innovation, decision making and learning: in this latter case the nature of the KA cannot be decoupled, nor generalized, from the specific setting or Community of Practice where the KA is supposed to play its role of knowledge facilitator. The first studies of communities where the creation and circulation of new knowledge is part of the practices that foster sense of belonging and identity therein led to characterize a specific kind of community, denoted as "knowing community" (Cabitza et al, 2014), which is defined as the social gathering around a KA and where actors interact also in virtue of the KA mediation. To account for this mediating capability, specific principles have been proposed for the design of situated KAs, namely, representational locality, semantic openness, and flexible underspecification, and discussed in (Cabitza et al., 2013). Differently from the representational KA, the quality of the situated KA cannot be proved formally, but rather assessed in terms of user adoption, appropriation and satisfaction towards knowledge work support, that is in terms of the extent users consider the KA fit to their needs and capable of triggering social interactions that would allow them to create, socialize and diffuse new knowledge. In Figure 2, we denoted this capability "socio-technical fit" (in the bottommost hemiplane) as this is certainly an attribute that a KA does not possess independently of the social setting in which it is adopted, but rather something depending on many factors that go beyond the merely computational and performance-related aspects of the artifact. As locality is important for situated KAs (by definition itself of situation), any strong or strict structure hardwired in the artifact at design time could undermine, or just hinder, the processes of user appropriation (Dix, 2007) and evolutionary growth (Mørch, 2003) the KA must somehow undertake to support a knowing community over time. For this reason, the capability of the KA to be adapted, configured, and tinkered by end users themselves to improve the above mentioned fit is the second dimension on which prospective situated KAs can be assessed (see Figure 2, bottommost hemisphere).

Based on the literature review, future research can address several directions. First, the literature review highlights the diversity of KAs; we suggested a typology based on two dimensions, i.e. objectivity and situativity. However, other proposals and taxonomies are possible. On a more conceptual level, our categorization can also be taken as a contribution for a scholarly debate still to be developed, regarding what features should a KA exhibit, and on what kind of priorities to focus on with respect to the application domain or community. A major attention to the social practice aspects of knowledge, for instance, could motivate the design of artifacts that are made to be local, in continuous evolution, and to host necessarily incomplete, and possibly partially inconsistent and ambiguous representations.

These only seemingly paradoxical features should not then be taken as deficiencies of the tools conceived to support knowledge, but rather as features that result from a deep understanding of the semiotic nature of human representations (Gourlay, 2004) and that require a committed research agenda in the next years to come to be fully realized in running applications and knowledge artifacts.

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