Visual Representations as Carriers and Symbols of Organizational Knowledge

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ABSTRACT
In this paper, we conceptualize visual representations (e.g., sketches, CAD drawings, and prototypes) as 'artifacts of knowing' serving the purposes to share, transform, and symbolize organizational knowledge. First, we propose a comprehensive definition of visual representations by integrating insights from the literature domains of knowledge management and organizational culture. Building on the reviewed literature, we then develop a conceptual framework that articulates the visualization process in terms of a cyclical pathway between the *formats* (e.g., from sketches to prototypes) and the *functions* (e.g., from knowledge sharing to knowledge symbolization) of visual representations. After suggesting managerial recommendations for the use of visual representations in organizational knowledge management, we conclude our paper by pointing out the limitations of the current literature, and by suggesting directions for future research on visual knowledge management.

Categories and Subject Descriptors
M.0, M.4, M.8

General Terms
Management, Design, Human Factors, Theory.

Keywords
Visual representations, boundary objects, symbolic artifacts, conscription devices, organizational culture, knowledge management, knowledge visualization, visualization software, design engineering.

1. INTRODUCTION
A prime objective of knowledge management is to make knowledge *visible*, and therefore more accessible, tangible and valuable to members of an organization. As suggested by Eppler and Burkhard [8], the emerging field of *knowledge visualization* examines the use of visual representations to improve knowledge management at the individual, team, and organizational levels. In this paper, we use the term *visual representations* to designate all the graphic means used to construct, share, and transform knowledge in *organizational settings*.

We structure our paper as follows: First, we provide a definition of visual representations by drawing on Whyte et al.'s [29, 30] concept of visual fluidity. We then discuss different theoretical perspectives on visual representations, making an attempt to bridge the concepts of *boundary objects* and *symbols* – as developed in the literature streams on knowledge management and organizational culture. On the one hand, the literature on knowledge management – and knowledge visualization in particular – has focused primarily on *functional* aspects, such as the advantages and disadvantages of different formats for visual representation [2, 9, 22]. On the other hand, the literature on organizational culture has interpreted visual representations as *symbolic artifacts*, namely as 'visual reifications' of organizational values and assumptions [6, 13, 24].

By integrating different theoretical perspectives, we intend to provide a comprehensive conceptualization of visual representations that takes into consideration functional, material, and symbolic components. We thus develop a conceptual framework that articulates the visualization processes occurring during interactions among organizational actors. In particular, we describe the visualization process in terms of a cyclical pathway between the *formats* (e.g., from sketches to prototypes) and the *functions* (e.g., from knowledge sharing to knowledge symbolization) of visual representations.

To illustrate our conceptual framework, we focus on the organizational domain of *design engineering* – a broad term that covers multiple disciplines such as building, mechanical, and product engineering. In design engineering, visual representations are central to the work activity and represent the outcome of a knowledge-intensive process. Therefore, this domain is particularly suitable for the purposes of understanding visual representations as 'artifacts of knowing'. We begin by proposing a typology of visual representations used in design engineering, and we subsequently present an illustrative case of visualization practices in such a domain.

Finally, we discuss the managerial implications of our conceptual framework and – recognizing the increasing relevance of computer support in a variety of domains – we provide recommendations for improving the use of visualization software. We conclude our paper by pointing out the limitations of the current literature, and by suggesting possible avenues for future research.

2. DEFINITIONS AND THEORETICAL PERSPECTIVES ON VISUAL REPRESENTATIONS

2.1 Which Visual Representations? 'Fluid' versus 'Frozen' Visuals

With a few exceptions [8, 9, 29, 30], scholars have used the term 'visual representation' in a broad sense, neglecting important differences between visualization types. Among the few exceptions, Eppler and Burkhard [8] acknowledge that visual representations may serve different *functions*, depending on the *format* used for representing knowledge. Whyte et al. [29] further suggest to distinguish between 'fluid' and 'frozen' visual formats: Fluid visuals are dynamically altered throughout the discursive practice, whereas frozen visuals remain unchanged while being discussed by organizational participants. However, the distinction between 'fluid' and 'frozen' is not absolute, but rather is a matter of degrees, with grey zones in between the extreme ends of the continuum. Furthermore, practitioners can engage in the actions of 'freezing' and 'unfreezing' visual formats to pursue diverse purposes in their work activity [29]. For example, a 'talking sketch' drawn simultaneously by two or more engineers may be frozen into a 'quick and dirty' prototype, (i.e., a prototype that is not created from precise design specifications but rather is assembled from provisionary materials to approximate the final product) [17]. While fluid visuals are more suitable for framing problems and exploring solutions, frozen visuals enable keeping a legitimate record of, and winning commitment to the negotiated solutions [29]. In the next paragraphs, we proceed by reviewing theoretical perspectives on visual representations, as elaborated in the literature domains on knowledge management and organizational culture. As we will see below, knowledge scholars have defined visual representations as boundary objects, while organizational scholars – in particular symbolic interpretivists – have favored a symbolic perspective on visual representations.

2.2 Visual Representations as Boundary Objects

According to Star and Griesemer [27], boundary objects are robust enough to maintain a common identity across knowledge domains, yet plastic enough to adapt to the needs and constraints of the diverse actors employing them. As exemplified by Fujimura [12], the concept of gene can be understood as a boundary object, for carrying common meaning across biology, pharmacy, and finance, while also receiving idiosyncratic connotations in each discursive arena. Being weakly structured in common use, and strongly structured in individual use, boundary objects facilitate knowledge integration across different work practices [27].

Drawing on the seminal work by Star and Griesemer [27], Carlile [3] distinguishes three types of boundary objects: First, *repositories* (e.g., cost databases) supply a common set of data, therefore working as reference points for coordinating different activities. Second, *standardized forms and methods* (e.g., engineering change forms), provide a shared format for discussing, and solving problems across functional departments. Third, *objects, models, and maps* are "simple or complex representations that can be observed and then used across different functional settings" [3]. In particular, *maps* – broadly defined as Gantt charts, process maps, and workflow matrices – help clarify the knowledge differences and dependencies among organizational functions. According to Carlile, objects, models, and maps – and hence visual representations – are the only category of boundary objects that enable not only to share, but also to negotiate different understandings. In effect, in order to apply and transform the knowledge used at a boundary, individuals must be able "to *draw on*, *alter*, or *manipulate* the content of a boundary object" [3] – a function supported by objects, models, and maps.

Whereas Carlile [3] suggests that "sketches, assembly drawings, prototype assemblies, mock-ups, and computer simulations" all support knowledge sharing and transformation, Henderson [18] argues that fixed drawings – such as computer aided designs – are too rigid in order to work as boundary objects. In her studies on design engineering, Henderson proposes to consider only flexible drawings as boundary objects or, in her words, as 'conscription devices' – a term that captures the interactive nature of visual elements used in collaborative processes [16-18].

While we acknowledge that fluid visuals – by virtue of their greater malleability – are more apt for transforming knowledge at a boundary, we refrain from categorically excluding frozen visuals from the definition of boundary object. For example, CAD drawings can be co-constructed in collaborative settings, and interaction with prototypes may enhance knowledge by means of providing a sensorial experience. Moreover, the distinction between frozen and fluid formats is rather nuanced, and the processes of freezing and unfreezing are strictly intertwined in a continuous cycle. As we will discuss below, we nevertheless recognize that frozen visuals, such as clean drawings, computer designs, and final prototypes, results out of the process of knowledge sharing, and hence are more suitable to embody, represent and *symbolize* the collective knowledge of organizational actors.

2.3 Visual Representations as Symbolic Objects

In the literature on organizational culture, visual representations are usually classified within the broad categories of *artifacts* and *symbols*. According to Schein [26], *artifacts* are grounded in values and assumptions, and represent the most visible, tangible, and audible aspects of organizational culture. Organizational culture can be explained with an iceberg metaphor: On the surface are artifacts, below artifacts lie values (i.e., guiding principles) and at the basis are assumptions (i.e., taken-for-granted beliefs). As an example, Yakura [31] argues that visual artifacts such as PowerPoint presentations "carry cultural codes that communicate and reinforce values and assumptions".

Apparently similar to artifacts, *symbols* are defined as anything that points to a higher-level concept or meaning [15]. Eisenberg and Riley [6] and Gioia [13] provided an exhaustive record of organizational symbols, including visual representations such as charts, images, and metaphors. While symbols and artifacts are indistinguishable as regards their physical forms [15], symbols are loaded with, and carry on meaning. In other words, symbols are not merely representations of values and assumptions, but also means of sensemaking and sensegiving [4, 15, 25]. As reported by Hatch [15], Cohen [4] argued that symbols "do more than merely stand for or represent something else ... they also allow those who employ them to supply part of their meaning".

In her study on the dynamics of organizational culture, Hatch [15] further clarifies the distinction and the inter-connection between artifacts and symbols, by introducing the concept of prospective and retrospective symbolization. At first, organizational actors can engage in *prospective symbolization* by loading an

artifact's literal meaning (e.g., a mahogany desk) with a higher-level meaning (e.g., social status) that reaches beyond, and surrounds the material domain. In turn, organizational actors can engage in *retrospective symbolization*, by re-constructing the artifact as a physical object on the basis of their symbolic memory. Hatch [15] further argues that "artifacts must be translated into symbols if they are to be apprehended as culturally significant objects, events or discourses … although all artifacts can be symbolized, not all will be, at least not all times and places, for all organizational members".

Building on our literature review, we argue that frozen visuals are more likely to carry symbolic meaning, being the *product* of collective sensemaking, and reflecting the shared experience of organizational actors. Fluid visuals, by contrast, are employed in the *process* of collaborative interaction, and are flexibly manipulated for the co-construction of meaning. As we will discuss below, Hatch's [15] concept of prospective and retrospective symbolization parallels Whyte et al.'s [29] notion of freezing and unfreezing. In turn, these coupling concepts lay the ground for the development of an integrative framework where visual representations are conceived as both boundary and symbolic objects.

3. AN INTEGRATIVE FRAMEWORK OF VISUAL REPRESENTATIONS

In the previous section, we have described visual representations through the theoretical perspectives of knowledge management and organizational culture. In this section, we propose an integrative conceptualization of visual representations, by bridging the notions of boundary and symbolic objects. In doing so, we also attempt to capture the dynamics of visualization in organizational settings by articulating the processes of freezing and unfreezing, prospective and retrospective symbolization of visual representations (Figure 1).

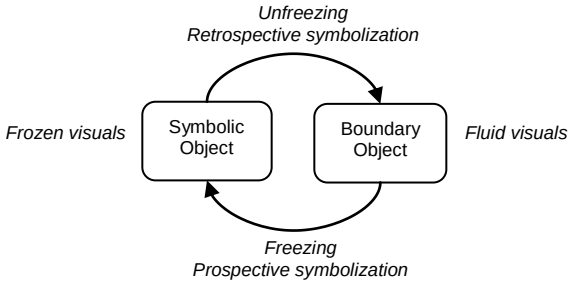

Figure 1. An integrative framework of visual representations as artifacts of knowing

As shown in Figure 1, we suggest a cyclical pathway between boundary and symbolic objects, occurring through iterative processes of freezing and unfreezing, prospective and retrospective symbolization. At first, visual representations are co-created in interaction, and serve the primary purposes of sharing and transforming knowledge across boundaries. As suggested by Carlile [3], visual representations act as *boundary objects*, enabling actors to negotiate their knowledge for the co-development of shared understanding. Since the process of knowledge transformation at a boundary requires to interactively draw on, alter, or manipulate objects, we argue that *fluid visuals*, such as sketches, are most suitable to act as *boundary objects*. Towards the end of their interaction, participants will refine, and formalize their shared knowledge into frozen visuals, such as clean drawings (*freezing process*). At the same time, participants will load the final object with symbolic meaning, and will elaborate symbolic memories of their collaborative interaction (*prospective symbolization*). As mentioned above, *frozen visuals* are more likely to work as *symbols*, since they embody the collective meaning developed by organizational actors. During subsequent interactions, physical contact with the frozen materials may provide further insights, and require participants to revert to fluid visuals in order to renegotiate, and refine their common understandings (*unfreezing process*). At this stage, actors are likely to give more emphasis to the physical components of the visual object, thereby engaging in a process of *retrospective symbolization*. In this conceptual framework, visual representations can be seen as 'artifacts of knowing' – an expression we borrow from Ewenstein and Whyte [10] – since they are *carriers* and at the same time *symbols* of organizational knowledge. In the next section, we illustrate our conceptual framework by making reference to design engineering, and suggesting possible applications to other knowledge-intensive domains.

4. VISUAL REPRESENTATIONS IN WORK PRACTICES

4.1 A Typology of Visual Representations in Design Engineering

In this paragraph, we propose a classification of the types of visual formats used in design engineering, ordered from the most (i.e., sketches), to the least fluid (i.e., prototypes). As classification principle, we therefore adopt the concept of *visual fluidity* [29], or (as alternative terms for the same idea) modifiability [19], flexibility [18], or viscosity [14].

Sketches. Sketches are hand-drawings assisting the primary purposes of knowledge exploration, externalization, and refinement [18, 30]. As pointed out by Eppler and Pfister [7], "sketching can be considered as a tool of thought that enables the mind to capture things which are in flux and iteratively refine them". Therefore, sketches are used to try out new ideas, to compare alternatives and, most importantly, to capture 'fleeting thoughts' on paper [21]. In design engineering, a distinction is made between conceptual and technical sketching [11]: The *conceptual sketch* – as an external fixation of ideas – is used to guide non-verbal thinking, and to provide the early specification of the design concept. The *technical sketch* (Figure 2) reproduces the form and function of the final product, and is used in a subsequent stage of the design process to direct a draftsman in making a finished drawing. While sketches are often drawn for individual thinking, several authors document the collaborative use of sketches [7, 11, 17, 21, 28]. *Talking sketches* – co-constructed by engineers passing one pen back and forth [17] – are used to clarify, discuss, and negotiate complex aspects of the design concept [11, 21, 28]. By virtue of their collaborative and informal mode, talking sketches enable participants to engage in an open dialogue, and to actively listen each other's viewpoint.

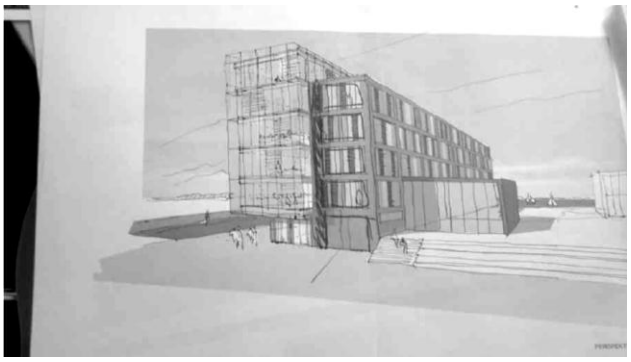

Figure 2. Technical sketch of a four-storey building: A relatively fluid visual (Source: [1]**).**

CAD drawings. CAD (i.e., computer-aided design) is the use of computer technology for the detailed drawing of physical objects (e.g., buildings, products, machines). While sketches focus on relatively few issues at a time, CAD drawings can encompass multiple layers of complexity, and are usually integrated with computerized data bases [1, 18]. CAD drawings present different formats, from *two-dimensional*, plain representations to *three-dimensional*, highly realistic renderings (Figure 3). 2D and 3D CAD software are often used in combination: The first enables the designer to actually draw the object from technical sketches, and the second to show how such an object will ultimately look like. Being nearly perfect representations of the final product, CAD drawings are fixed in nature, and can be defined as the "officially recognized carriers of design information" [18]. However, CAD drawings present little materiality, at least in comparison to prototypes, and can therefore be modified with a certain easiness, by means of either hand-drawn notes or computer-made revisions. With an example from the architectural practice, Bendixen and Koch [1] note: "During the briefing [with the client], a storey of a building can be added or deleted through a few CAD operations. Since the negotiations are on an 'appearance level' of the building, this can be done swiftly … without losing substantial amount of design work". CAD drawings – especially 3D – thus seem to be particularly suitable in an advanced phase of the project work, when the core concept has already been developed and only needs to be refined.

Figure 3. 3D CAD drawing of a four-storey building: A relatively frozen visual (Source: [1]**).**

Prototypes. Prototypes are three-dimensional representations of the final product (e.g., building), and can thus be considered as physical models. As pointed out by Henderson and Law [17, 20], prototypes are frozen materials, with the exception that working parts can be cut to make the object slightly smaller. In order to actually manipulate the prototype, designers must revert to paper representations, in a 'metamorphic dyad' between object and paper [17]. Within the broad category of prototypes, we can nevertheless identify different degrees of fluidity, as suggested by Henderson's [17] distinction between *quick and dirty* versus *pre-production prototypes*. In any case, the very interaction with a plastic object provides actors with affordances for envisioning changes, refinements, and improvements to the final product. In the words of Henderson, "the prototype is both the source of old knowledge, and a vehicle for generating new knowledge" [17].

4.2 An Illustrative Example of the Integrative Framework

An example adapted from Henderson [17] may be useful to illustrate our integrative framework of visual representations as 'artifacts of knowing': Henderson observed an engineering project carried out at a company manufacturing high-precision miniature lenses. In this project, the designers were requested to create an innovative medical instrument to be used by surgeons to implant tiny lenses into the human eye. In the following paragraphs, we revisit Henderson's case study through the conceptual lenses offered by our integrative framework.

As reported by Henderson, the first documentation of design ideas emerged from 'sketching conversations' between a technician, a drafter, and the project engineer. The importance of the first set of drawings was expressed by a consultant in mold injection techniques: "As soon as the first sketches are shown to another pair of eyes, suggestions for changes start. Ideas expressed only verbally can be forgotten, but once they are made specific through concrete depiction they gain in stature". The first sketches helped organize the team interaction, while also clarifying the designers' ideas with respect to the general vision of management and other departments. This narrative shows how *fluid visuals* (i.e., sketches) work as *boundary objects*, by facilitating the construction of shared meaning across functional boundaries.

After several iterations from sketches to drawings and back, a pre-production prototype was assembled to simulate the appearance, and the functioning of the final product. At this stage, the visual material had already undergone a major trajectory of transformation, and become stable in a fixed format. The prototype went through a series of trials in order to be compliant with the highest standards for use in medical practice. At the same time, advocates and adversaries alike – among them investors, lawyers, and surgeons – had to be convinced about the viability of the final product. In Henderson's words, the prototype entered "the competitive world of corporate capitalism in a role that is a mix of political organizer, heroic survivor of innumerable trials, and recruiting sergeant". This account illustrates the process of *freezing*, whereby *fluid visuals* (i.e., sketches and drawings) are turned into *frozen visuals* (i.e., pre-production prototype). At the same time, Henderson suggests that the prototype was loaded with symbolic meaning, taking on the political connotation of a consensus and network builder (*prospective symbolization*).

In the conclusive section of her narrative, Henderson describes a further metamorphosis of the visual material: "When members attended the meetings, their introduction to the prototype ap-

peared successful … However, as members went back to their own departments, other interests took higher priorities, and problems arouse in the transition from the prototype to product. As the design concepts remain unmalleable when molded into plastic, designers had to return to paper representations to access the flexibility of sketches". This account illustrates the process of *unfreezing* visual representations from *frozen* to *fluid* formats, and at the same time suggests how organizational actors gained an increased awareness of the material components of visual artifacts, through a process of *retrospective symbolization*.

4.3 Further Applications

While our case illustration is focused on the domain of design engineering, the conceptual framework in Figure 1 is applicable to a variety of work practices. In fact, the cyclical pathway between fluid and frozen visuals – and the associated processes of prospective and retrospective symbolization – applies to all knowledge-intensive activities. In project management, the conceptual sketch of a timeline can be iteratively refined by organizational participants, and ultimately frozen into a Gantt chart to be included in a business report. In business planning, entrepreneurs can jointly discuss and design the company's business model, starting with a conceptual sketch and ending with a polished drawing to be used for communication with venture capitalists (freezing process). If venture capitalists request revisions to the company's business model, the entrepreneurial team may revert to fluid visuals for capturing, and incorporating additional elements into the business model design (unfreezing process). In the freezing process, the business model design is likely to be loaded with symbolic connotations, being the object of intense discussions and possible conflict among the members of the entrepreneurial team. In the unfreezing process, the business model design is progressively decomposed into its building blocks, therefore reassuming a pragmatic and material connotation. In addition, the entrepreneurs may use visualization tools to facilitate business planning, very much like engineers use CAD software as a support to the design process. As an example, the business model canvas (Figure 4) by Osterwalder and Pigneur [23] is a visual template showing the constitutive elements of a business model. This hands-on tool can be printed out on a large poster and filled with post-it notes and board markers in a business meeting context.

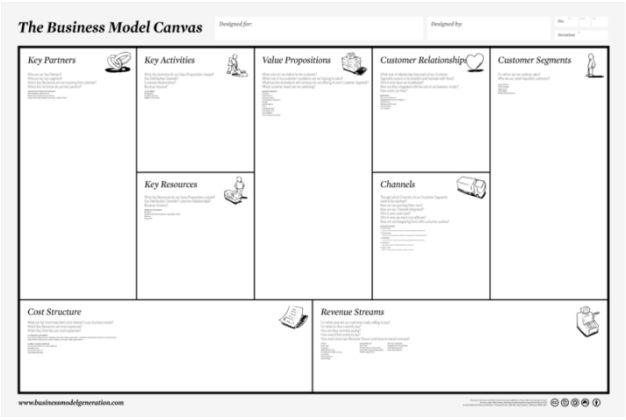

Figure 4. The business model canvas (Source: [23])

As a visual representation, the business model canvas represents an intermediary degree of fluidity: On the one hand, a relatively frozen background provides a graphic setting for knowledge mapping. On the other hand, relatively fluid items are interactively mapped by organizational participants within such a setting. The business model canvas may be used also in combination with electronic support – e.g., loaded as a file in a visualization software or used as an application on an electronic tablet – therefore acquiring a more frozen aspect in its final, printed version.

5. CONCLUSION AND DISCUSSION

5.1 Conclusion

In this paper, we have developed a conceptual framework of visual representations in work practices, by integrating the theoretical perspectives of organizational culture and knowledge management. At first, we have proposed a definition of visual formats, by introducing Whyte et al.'s [29] distinction between *fluid* and *frozen* visuals. Afterwards, we have described visual representations through the theoretical lenses of *boundary* and *symbolic objects*. Therefore, we have developed an integrative conceptualization which takes into consideration both the material, and the symbolic meaning of visual representations. Drawing on the concepts of *freezing* and *unfreezing* [29], and on the notions of *prospective* and *retrospective symbolization* [15], we have proposed a dynamic model to articulate the material, and symbolic transformations of visual representations throughout collaborative processes. Finally, we have illustrated our conceptual approach by proposing examples from diverse work practices, most notably design engineering. Although our paper remains conceptual in nature, in the next section we derive a few managerial implications and recommendations for the use of visualization software. We conclude by pointing out the limitations of the current literature, and suggest avenues for future research on visual representations as 'artifacts of knowing'.

5.2 Managerial Implications

The application of our integrative framework should increase managers' sensitivity to the political and symbolic connotations of visual representations. In this regard, managers should knowingly use frozen visuals to secure the commitment of supporters, and to prevent political maneuvering on the part of detractors. As suggested above, in the transition from fluid to frozen the visual integrates layers of knowledge, and at the same time becomes a political actor by virtue of its definitive shape. However, managers should not abuse the persuasive power of frozen visuals to garner political support. Rather, they should strive for balanced decision-making, by enabling organizational actors to get access, and give shape to fluid visuals.

Furthermore, the application of our conceptual framework may lead managers to fine-tune their use of visual representations, and in turn to increase the productivity of their work practices. As an example, meeting facilitators should use fluid visuals during the initial stages of a collaborative negotiation, and promote the transition to frozen visuals only when the participants have reached common understanding and consensus. While a few iterations between fluid and frozen visuals may be unavoidable, a premature shift to frozen materials may be time consuming, and increase the risk of power conflict among participants.

Finally, our conceptual work has implications for improving software support: In design engineering, the early use of CAD software may provoke premature commitment to an imperfect product, and produce a waste of time – given the need to revert to fluid visuals, re-conceptualize the design features, and build consensus around the revised design [16, 17]. In business meet-

ings, visualization software is often used during the initial stages of a collaborative project, yet the software functionalities may at times be too rigid to facilitate brainstorming, team building, and shared understanding. Moreover, the background templates provided by visualization software – as the business model canvas in Figure 4 – may induce participants to neglect topics that are not displayed on the template labels. In effect, pre-fabricated templates provide an affordance to fill out empty categories, therefore inducing team members to jump into the task at hand, without taking the time to go through a more open reflection process [5]. As software is becoming increasingly relevant in a variety of work practices and tends to be used throughout all the stages of a collaborative project, it is important to integrate both freezing and unfreezing mechanisms in the software design, and to provide users with guidance in the selection of ready-made templates. For example, Visio has a layering functionality whereby the user can freeze previous layers, and fluidly add further layers. The software package of let's focus has a screenshot functionality, which works as a freezing mechanism whereby the user can capture a given moment in time. In the design of CAD systems, a real challenge consists of integrating fluid visualization – such as the sketching activity – to support concept development. While sketching packages are already available, CAD systems still have a long way to go before they can reproduce the naturalness of pen and paper sketching. Nevertheless, the integration of design activities in a software environment would enable users to combine the immediacy of freehand sketching with the advantages of storage facility, faster search, durability and permanence offered by computer support.

5.3 Limitations and Directions for Future Research

In this paper, we have made an attempt to integrate different literature streams, namely organizational culture and knowledge management, including the emerging field of knowledge visualization. We have seen the potential of integrating them, since we have recognized the limitations of both the theoretical perspectives, and the possibility of developing a more comprehensive view on the same object of study. On the one hand, the literature on knowledge management and visualization has largely neglected the *symbolic connotations* of the visual artifacts used in collaborative settings. On the other hand, the literature on organizational culture has emphasized the symbolic component of visual artifacts, while also recognizing the need to appreciate their material dimension [15]. Even so, this literature stream has failed to consider visual representations as a distinct type of organizational symbols, and to appreciate the *functional implications* of using different visual formats. Therefore, visual representations have been inserted within broad categories, together with completely different symbols – such as dress codes, actions and non-actions, and corporate stories [13]. Not surprisingly, the literature on organizational culture – and symbolic interpretivism in particular – has completely neglected differences in the *fluidity, or malleability* of visual materials. While we have made an attempt to bridge the two literature streams around an integrative definition of visual representations, we acknowledge the limitations of our conceptual work, and accordingly point out directions for future research:

First, our integrative framework is purely conceptual, and needs to be refined through empirical research on the use of visual representations in collaborative settings. Therefore, future research should address the following questions: When do boundary objects become symbolic objects and vice versa? What are the in-between states that such objects take during the transformation process? Given the in-depth nature of the subject under study, and considering the developmental stage of our conceptual framework, we believe that qualitative, ethnographic methods – such as participant observations – are most suitable for empirical research.

Second, our re-reading of the case study by Henderson [17] suggests that organizational symbols are far from receiving a unique interpretation, and may be loaded with contradictory meanings. While boundary objects enable the construction of a *shared* understanding across boundaries, the use of symbols seem to be associated with power *conflict*. This may be the case, because the rigidity of the visual material used in symbolic objects gives less room for collaborative re-negotiations of meaning. We believe that this topic – i.e., the linkage between symbolic objects and power conflict, versus the linkage between boundary objects and consensus seeking – deserves further consideration, both in terms of conceptual refinement and empirical observation.

Finally, whereas the integrative framework has a wide applicability, the typology of visual representations is somewhat idiosyncratic to the domain taken into consideration – in our case, design engineering. Interested scholars may consider extending our work, by applying our conceptual approach to other domains. In Section 4.3, we have suggested further applications to the domains of project management and business planning, but the broad domains of arts, business, and science are all valid test beds for the study of visual representations as "artifacts of knowing".

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