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Bridging Artifacts and Actors: Expertise Sharing in Organizational Ecosystems

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Abstract. We synthesize findings from longitudinal case studies examining work practices in three different organizations and propose analytical and methodological frameworks to guide the design and implementation of technologies for expertise and knowledge management. We appropriate the concept of ecosystem to argue that we can create active and useful solutions for knowledge management through a focus on interaction between two mutually intertwined elements of an ecosystem—artifacts and actors. We show that in expertise and knowledge sharing systems domain knowledge and technological knowledge are complementary and we present evidence that small solutions can have far reaching effects. Finally, we make a case for full integration of IT developers as an element of expertise sharing ecosystem.

Key words: knowledge management, expertise sharing, case studies, IT ecosystems, CSCW

1. Introduction

The value of expertise sharing within organizations is well established. The terrain of knowledge management (KM) research program is vast and researchers have explored numerous theoretical issues as well as software applications (e.g. Ackerman and McDonald 1996; Alavi and Leidner 2002; Civan-Hartzler et al. 2010; Cross et al. 2001; Cummings 2004; Ehrlich and Shami 2008; Faraj and Sproull 2000; Hansen 1999; Orr 1990; Saeed et al. 2010; Schultze and Leidner 2002). The role of information technology in managing knowledge in organizations has specially been a fertile area of research and scholarship within CSCW. Starting with the influential approach suggested by "Answer Garden," research on knowledge management undergone several crucial iterations (Huysman and de Wit 2004). In spite of recent developments, the approach outlined in Answer Garden remains salient because by providing a solution to a seemingly common contradiction within organizations—the lack of incentives for experts to repeatedly share the same piece of information (even within the same company)—it centrally established the role of information technology in knowledge management, giving this line of work legitimacy within CSCW. The key innovation it suggested was that knowledge management requires

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the integration of the information space (knowledge artifacts) with the communication space (social interactions) (Huysman and Wulf 2006). The combination of information and communication spheres has proven to be a sustaining idea that has been reinvented over and over since then, with 'social software' such as Wikis and Social Networking being the latest advancements that have found legitimacy within organizations (Johri 2011a). In addition to its recommendation to leverage the information and communication space, Answer Garden (AG) also documented the importance of orienting any KM solution towards a specific domain (e.g. knowledge exchange around X-Windows programming, which was the original target domain of AG). This domain orientation assures the blending of the solution with already existing knowledge practices thereby respecting the needs of both the expert and novice stakeholders (Pipek and Wulf 2003). Although the solution offered by Answer Garden has had a significant impact, it suffers from some significant limitations: (1) The solution suggested by the AG approach—externalization of knowledge—created a predicament since the 'learner' now required assistance with re-contextualizing the knowledge represented in the document again necessitating interaction with the 'expert', (2) The AG approach paid cursory attention to situating the solution within an organizational context, although it hinted that contextual implementation is important particularly in relation to domain knowledge, there was no substantial discussion of implications beyond the narrow aspect of domain knowledge, and, (3) The solution also suffered from a limited view of experts and novices where it characterized their roles in a binary fashion, whereas in organizations this distinction is increasingly amorphous (a distinction partially recognized and addressed in Ackerman and McDonald 1996). Scholars soon realized that in practice the role of information technology is inherently more complex and the role technology plays can be better understood as a support for sharing knowledge and expertise, rather than managing it.

We have revisited the Answer Garden approach in depth as many scholars, including us, owe a debt to the central ideas that emerged from that work and also because it provides a point of departure for later studies that have gone on to examine the idea of knowledge and expertise sharing critically, such as our research program. Following initial work in KM, researchers have identified several challenges in the fit of designed technologies with their purpose in practice, particularly as observed through field studies (Ackerman et al. 2003; Cohen and Prusak 2001; Huysman and Wulf 2004; Reichling and Wulf 2009). For instance, actors often have different skills, goals, or cultural backgrounds which can lead to the failure of IT systems (Pipek and Wulf 2003; Normark and Randall 2005; Reichling and Veith 2005). Even the successful application of new technologies can have unexpected individual or organizational outcomes that are contrary to the initial goals (Orlikowski 1996; Pipek and Wulf 1999). Moreover, implementations are hard to sustain as technology use takes a long time to stabilize and integrate with existing practices (Barley 1986; Orlikowski 1992; Pipek and Wulf 2009), as a result, many systems end up as one-time experiments.

There have been some successes in practice (e.g. Bobrow and Whalen 2002) and the primary lesson that emerges from these studies is that integration of technology within the organizational context is critical and there is greater need to examine the practice of knowledge and expertise sharing through field studies (e.g. Ackerman 1998; Ackerman and Halverson 1998; Becks et al. 2004; Orlikowski 2000; Ehrlich 2003; Fagrell 2003). The basic motivation for our work has been a reinvestigation and re-conception of the knowledge management research program by striving to connect the need for technology that supports knowledge and expertise sharing with the work practices of an organization (Bannon and Kuutti 1996; Ackerman et al. 2003; and Barley and Kunda 2001). The question that guides our empirical work—what do people actually do in this organization and how can we support their knowledge sharing needs—also directly leads to our research methodology whereby we focus on uncovering the tacit aspects of work practices using a grounded and interaction oriented approach.

In this paper we synthesize three research studies to uncover cross-cutting design principles for designing knowledge management systems. We reemphasize that a persistent design and research challenge in the development and implementation of knowledge management systems is uncovering aspects of work practice that need to be supported and show that, although seemingly simple, this process is complicated by a practical contradiction that the introduction of a novel technology—any knowledge management system—changes the very practices that it aims to support. We found that the ideal design solution provides space for novel work practices to develop around the technology; in other words, it takes unanticipated consequences and second-order effects as a part of design and the solution. We appropriate the notion of an "ecosystem" to argue that developing knowledge management systems not only requires an understanding of localized social practices, which are the direct target of technology implementation, but cognizance of the larger context to support the emergence of new practices. This is a delicate process and the metaphor of an ecosystem captures all the factors that need to be balanced. Through our research program we have developed an analytical framework that we argue provides significant assistance in designing and implementing ecologically-valid systems. Our framework outlines two "meta" design approaches that suggest that in any given context a KM system needs to privilege either the support of knowledge artifacts or the support of activities undertaken by actors. In other words, we argue that only one aspect should be constrained by the design and not the other. Our research further demonstrates that even simple technological mechanisms if embedded in a symbiotic manner within an ecosystem can have a significant effect on knowledge and expertise sharing practices. In addition to furthering our analytical understanding, our approach and findings also have implications for design and we leverage the idea of an ecosystem and ecological design framework.

Next, we discuss our research approach and follow it by an overview of three longitudinal case studies that serve as the empirical basis for our analytical and theoretical contribution. We then review the findings through the lens of the duality of artifacts and actors within an ecosystem and we end with a conclusion section. We use the terms knowledge management and expertise sharing interchangeably while discussing our work. For us knowledge management is essentially the sharing of knowledge and expertise.

2. Research approach

2.1. Guiding framework: research through design

Although our research methodology has historically been inspired by the organization and technology development (OTD) framework (Wulf and Rohde 1995; Rohde 2007), our approach is also accurately reflected in another emerging research methodology—Research through Design (RtD) (Forlizzi 2007; Zimmerman et al. 2010). The RtD approach recognizes the centrality of artifacts and actors to organizational life. This framework informs our field studies where in we focus on not just the technology within an organization but also look at the social and organizational aspects of the work place. This work follows closely on the heels of design-based research approaches that are becoming common in other disciplinary areas.

2.2. Data collection methods

Primarily, we draw on ethnographic methods of data collection in our research but our research process differs in one significant aspect from traditional ethnographic research—there is a much greater involvement of informants in our research and our data collection is closely driven by our desire to develop an intimate familiarity with the work practice of our informants. This is a crucial parameter for us since we need to develop a strong relationship with partner firms and informants so that we can actually implement and evaluate our systems with a firm context. This necessitates significant relationship and rapport building with informants since we have to sustain their involvement for longer periods of time, sometimes as long as 3 to 4 years. The specific data collection methods we use include participant observations, interviews, collection of archival material, and focus groups and workshops with informants. In different organizations different data collection method played a primary role depending on the work practice. Overall, an in-depth engagement with the field was the mainstay of our data collection process, and, the longitudinal nature of our research and long term association with key informants gives us confidence in our findings and gives our work credibility. Whereas we have evaluated some of the systems we have implemented, some systems have just been implemented and underwent partial evaluations. For all the case studies that will be discussed at least one round of preliminary data collection and design of technology have been completed. During the field study stage we pay special attention to the technology being used in an organization to understand how it is being used (or not) and can we leverage the existing technology into systems that we design. Our primary reason do so is to avoid over burdening workers with yet another technological system without understanding why. Also, we realize that often technology might not be the answer to their knowledge and expertise sharing needs and we want to very attentive to this in our field study.

2.3. Research process

Our research and evaluation process progresses along different cycles and in each cycle we go back to the field site to gather more data or feedback from the informants. In most of our case studies the following steps of data collection, analysis, and system design can be discerned (in practice we do not always move through these phases in a pre-determined fashion but based on the logics of a particular field site and there is significant feedback from the informants during technology design):

1. Analyze work practice in-depth: Enter the field and collect preliminary data, analyze the data and draw preliminary finding, discuss findings with informants especially ideas on how they can be translated into technology.
2. Design and develop artifacts: Once we have the requirements in place we design the technology including specific algorithms and user interfaces.
3. Implement and evaluate technology in the field: In the next we deploy these artifacts in the field. Often they are deployed as enhancements to technology that already exists in the field. The reason for deployment is to evaluate the artifacts in real world work settings and we work with the users to evaluate them.
4. Redesign artifacts: Often the first deployment suggest ways in which the technology we designed can be modified to better serve the users.
5. We take this information into account and redesign and redeploy the artifacts in the field.

3. Designing expertise sharing ecosystems

Central to our design approach is the concept of ecosystem. We conceive of an ecosystem as an organizational environment that consists of actors and artifacts (Johri et al. 2007). This conceptualization is similar to the definition of ecosystem in a biological sense where an ecosystem is said to consist of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water, and sunlight. Actors in an organizational ecosystem are workers, support staff, management, and so on. We use the term artifacts to characterize any product that has been designed by humans. After humans, and in relation with humans, artifacts are the primary means through which knowledge within an organization is shared, transferred, transformed, and represented. Artifacts are common to all organizations, but they differ in their affordances in terms of what they allow to be represented and hence across organizations artifacts vary depending on the practices of that organization. Within different organizations different affordances are needed for what technology should and can do and we can design based on these affordances. As in any biological ecosystem, for us both actors and artifacts are important area of foci while examining knowledge and expertise sharing practices and when implementing systems that change the ecology of the ecosystem. The concept of an ecosystem also allows us to shed light on our work—introduction of new technologies in an already existing environment. In biological ecosystems, when new elements are introduced they can often have disruptive effects. But biological ecosystems have the ability to rebound. Similarly, the introduction of new technologies can disrupt an existing ecosystem but there is also a likelihood that there will be a shift in existing practice and the ecosystem will be back in balance. Furthermore, sometimes the toxicity of an ecosystem is high making it imperative that new technologies be introduced to lower toxic levels. From our perspective we have to identify aspects of an organizational ecosystem that relate to us what works and what does not and how we can improve the overall ecosystem. As we discuss in depth through the case studies below, a focus on artifacts and actors within the ecosystem is our attempt to make provide guidance on how we make sense of existing ecosystems and the need to keep them balanced.

4. Artifact-focused design

To further explore the role of artifacts—one critical component of an ecosystem—we draw on a case study of designing for document management—in this case, technical drawings—in the maintenance engineering department of a major German steel mill (Hinrichs 2000; Pipek et al. 2000; Pipek and Wulf 2003). At the time of the study, the mill employed about 3,500 people and was structured into independent plant operating units, such as the coke chambers or the blast furnace. Various central units provided services to these plants and managed the mill. The maintenance engineering process involved different central and distributed organizational units as well as external service providers. Data were collected through 25 semi-structured interviews, observations of the workplace, and informal conversations and interviews with organizational members. In addition, we analyzed a large number of documents including technical drawings and descriptions of archiving processes. We held a number of workshops to discuss how to improve the maintenance engineering process.

A central organizational unit, the archives group, was responsible for storing technical documents related to the steel mill they maintained a 100 year old archive that contained more than 300,000 documents, including technical drawings, technical descriptions, list of parts, static information and calculations. The documents were largely filed in conventional paper form and saved on microfilm. In 1995, an electronic archiving system was introduced which contained more than 50,000 drawings; old documents scanned from microfilms or new ones stored in raster format. This system used a classification scheme based on 'Basic Numbers' that split the mill into plants and their components. Although this classification was meaningful for accounting and control purposes which broke the mill down based on cost centers, the classification was not meaningful for engineering purposes. Another classification system called 'Drawing Numbers' was also in use but suffered from being too arbitrary. The numbers were assigned based on temporal order of creation of drawings but lacked context. The existing archiving system was problematic on several counts including the appropriateness of centrally defined classification schemes; incompleteness of the central archives given the distribution of documents in local archives; lack of common ground among users to interpret and use existing documents; and, conflicts regarding the definition of classification schemes and the division of labor when updating central archives.

In a nutshell, our solution to the problem involved centralization of local archives but by supporting multiple views. To do this we came up with the idea of efficient assignment of metadata to allow for different classification schemes. We implemented this system by integrating this process into an existing Document Management System (Windream). We further facilitated the storage of documents in folders and efficient assignment of metadata. We label this solution "Context Grabbing" and we define it as a set of techniques which allows enriching individual documents by assigning values of context attributes in a time-efficient manner (Hinrichs et al. 2005); tool kits for context grabbing support users in capturing or modifying values of a whole set of context attributes, or for a whole set of documents. They are customized with regard to the existing local work practices in dealing with a given document collection. Our solution is an improvement over existing techniques as current approaches focus primarily on flexibility. Architectures should allow flexibly adding or modifying the represented dimensions of context (e.g. Trigg et al. 1999; Dourish 2000, Simone and Sarini 2001). However, it is not only a question of being able to define attributes flexibly. These attributes also need to be filled with values which may even change during a document's life time. The more attributes of a document's context are modeled and the more dynamic they change, the more classification work results (cf. Trigg et al. 1999). The primary lesson we learned from this study was the importance of classification schemes in relation to artifacts and their effect on knowledge and expertise sharing, especially, the role archival data, in this case documents, can play in facilitating this process. Our solution to the problem was facilitating different classification schemes, employed by different groups within the organization, by allowing efficient assigning of context data in the form of metadata.

After addressing the role of artifacts in the organizational ecosystem, we now turn to the role of actors and design focused on giving actors primacy when conceiving and developing a knowledge and expertise sharing intervention.

5. Actor-focused design

While focusing on actors, the other critical component of an ecosystem, we further differentiate between supporting a community of actors and connecting individual actors. When the goal is to support a community of workers, the solution is a long term support architecture that makes workers aware of the different expertise available in the organization. The primary goal when supporting individual workers is to design a system that supports immediate need for finding someone with requisite expertise. We realize that these approaches are not mutually exclusive and both needs can be and should be supported simultaneously but this distinction between the two approaches is still valuable from a design perspective as a focus on community leads to different assumption about the common ground between actors (they have more in common) as compared to an individual focused design. This separation will be further clarified in the discussion that follows.

5.1. Community-focused design

The second case study examined a freelancer network, SIGMA, which was an organization of consultants that come together to work on certain projects. This organization exists virtually, in the sense that it has no physical location, and people come together to work based on projects. This site was especially well suited to utilize technical tools to support expertise sharing given its networked nature and the needs of its members to work with each other and to work with different members based on the work to be done (Rittenbruch et al. 1998). For this study, we conducted 12 narrative interviews with network members of different kinds (hierarchical level, level of expertise, length of network affiliation). The interviews took between 45 and 120 min and most of them were recorded on tape. The interviews consisted of a free narrative part ("Please describe your work within SIGMA.") and more focused questions on knowledge acquisition and knowledge transfer in the second part. The narrative interviews were complemented by unstructured interviews with key role players (managing director, project manager). Membership in SIGMA provided financial, infrastructure-related or administrative services to the associates, who in turn contributed 10% of their turnover to fund the network services. In 1995, an "intranet" based on a Bulletin Board System (with a messaging system and file sharing areas) was introduced subsequently replaced by a "Lotus Notes"-based Intranet in 2000.

There was an acute need for expertise and knowledge sharing within SIGMA that sprung from the following sources: a person wants to ask an expert on a new field of expertise; a team leader has to find a new person with certain competencies since the "usual experts" are working in other projects; related competency availability from the customer perspective; redundancy avoidance through sharing of best practices; and, integration of new members through familiarity with existing expertise.

The usual organizational solution to address these issues consists of profile databases or similar information spaces. However, our initial observations (described in great detail in Mambrey et al. 2003; Pipek et al. 2003; Pipek and Wulf 2003) uncovered several points of failures, particularly the failure to establish expertise profiles in this highly dynamic organization. For instance, we found that the cost of updating the profile was considered too high compared to the possible benefits. There was also some resistance against the transparency of expertise as senior network members had trained junior members in relevant skills, and wanted to have exclusive access to 'their' team members. Concerns were also raised about the validity of expertise profiles since network members would claim expertise that they may not be able to deliver in a satisfactory way. Another significant barrier to creating profiles was the fear among individuals that by making their competencies explicit, they were also making explicit their lack of certain competencies. Finally, the descriptions of competencies were by far not unanimous. Experts from different educational and experience backgrounds would use different terms to describe similar knowledge or different expertise with the same words. The necessity to agree on a single ontology was argued to be one of the strongest points against a profile database.

Therefore, one of the challenges we decided to address in our solution was the difficulty of managing different expectations that actors had regarding the display of expertise across two conditions: (1) when they searched for expertise, versus, (2) when their own expertise was being displayed. As an information seeker, they wanted information to be as specific and accurate as possible, while they had numerous reasons to blur the presentation of their own expertise towards other information seekers. Therefore, our solution integrated two lines of inquiry. The basic idea was to integrate communication channels to experts into knowledge and best practice bases. Several authors (e.g. Ackerman and McDonald 1996) deal with the concept to enhance knowledge bases or case-based reasoning systems by communication channels (email, chat, voice, or video) that allow the direct communication with experts. To address the needs of the community as a whole, it was necessary to shape the interaction so that it became observable in an unobtrusive way. The first step is to find an expert. We supported the formulation of requests for expertise in terms of sharable beliefs (expressed in clauses hidden behind an easy-to-use visual interface) about what measurable events indicate expertise (e.g. visiting a website with a certain frequency, or attending a seminar in a certain knowledge domain, or engaging in an expertise communication about a certain topic) in a field. Aside from establishing a communication channel to experts when necessary, we also implemented notification services to provide peripheral awareness about gains and losses of available expertise in the community (Won and Pipek 2003). The goal is not to automatically "program" expertise in a database, but to enrich every individual's work context with up-to-date information for building a mental model of the expertise available in the community. Through this approach the characterization of expertise was left neither to a knowledgeable developer nor was it delegated to an automatic system which relied on an a priori model of knowledge. In contrast, knowledge reification was delayed until the system was in use and end users were allowed provide their representative needs.

5.2. Individual-focused design

Finally, we present a case study of a large industrial organization that has thousands of members within its fold and works as a network (Reichling and Veith 2005; Reichling and Wulf 2009). We show how we designed a system to support individuals working within this large umbrella organization in finding experts both within their departments and across departments.

NIA is one of the biggest confederations of industries in Europe with almost 3,000 member companies from a large variety of different branches. The association is divided horizontally into 37 sections, each dedicated to companies of a certain industry sector (like "agricultural technology", "lifts and escalators" or "pumps and systems" but all related to machine and plant construction) and vertically into general departments (like "business administration", "law" or "taxes"). In addition, NIA consists of several spin offs and other specific organizational units such as forums, projects and regional offices. At the NIA headquarters about 450 employees work in one of the organizations' sections or departments. Member companies pay for their membership according to their size. These payments go directly to the corresponding section. The sections pay a certain percentage of their fees for organizational overhead to finance e.g. the vertical departments. The payments of member companies are the main source of income for NIA. We collected data through observations and 16 semi-structured interviews (that were conducted within three cycles) with employees and managers of NIA. The majority of the interviewees were employees of the agricultural section; the others worked in several vertical units such as the staff-, IT- or standardization departments. The two managers headed the agricultural section and the IT department, respectively.

The decentralized organizational structure fostered the dedication of NIA towards the individual branches. However, the strict borders between the sections led to losses in potential synergies. So, due to a large mandate, the formal organizational structure within NIA was very heterogeneous and the formal and informal network was very complex. An additional obstacle was the relatively strict borders between branches, which made it hard to uncover network ties essential for fostering social networking. Informants suggested that mutual awareness about skills, expertise, experiences, and knowledge among the employees would bring them a "giant step forward". Specifically, we identified the following problems within the organization related to knowledge and expertise sharing given the large and heterogeneous nature of the organization: creating organizational transparency and gathering data; identifying competencies, abilities and responsibilities; lack of proper user-profiles reflecting the users' recent work; prevent the users from time consuming profile updates; encouraging users' motivation and reliability; reference to knowledge-representing artifacts is important; and, electronic media offer only insufficient support for this reference. Our research further showed that this information was unavailable in the association either through existing systems such as an "Address Information Management System (AIM)" that listed address information of employees or by the catalogue that lists contacts for specific topics. Employees needed an efficient and reliable search for appropriate experts in a given domain.

Our solution to address the need was based mainly—but not exclusively—on matching experts based on their texts. The architecture of the system was designed in an extendible manner to allow for more sophisticated recommendation strategies which include further indicators of expertise (Reichling et al. 2007). It allowed integrating modules which connect to a variety of different applications to access further types of relevant personal data. For instance email discussions, interaction histories, internet bookmarks or newsgroup postings may provide additional insights into the people's expertise. Appropriate modules capable of accessing these sources of data could thus extend the system's ability to create indicative user profiles. Moreover, the architecture allowed accessing its functionality via WebService technology. When analyzing the KM needs within NIA, many interviewees pointed to the fact that they did not want to get yet an additional application. They felt already overwhelmed by the number of applications they were using. The deployment of this 'Expert Finder' started with two strategies, a standard profile approach with self-description of expertise and with expertise descriptors derived from a text base provided by users. It showed that selecting documents was simple enough as an interaction for defining one's own expertise, and that it could motivate the creation and modifications of expertise profiles. It also showed that it is important to have different strategies available (and supported with IT) to support different expert seeking behaviors, and that these strategies are being used in combination and may stimulate improvements in the expert seeking behavior of individuals.

Given the continuous intertwining of information and communication spaces in the Internet in general and in organizational IT infrastructures in particular, our experiences allow us to point out some important guiding principles for the design of knowledge and expertise sharing systems. In all of the examples we gave it was not the innovativeness of a technological algorithm or interaction concept that decided on a final acceptance of an idea, but the quality of its fit into the existing ecosystem of the organization. We ensured that the ecosystem was not unbalanced, that is, our technology was not disruptive to the existing health of the ecosystem. Furthermore, as in any ecosystem there is always a prior ecology or practice of artifact production and consumption, and a prior communication practice, and in all three cases we started out with the basic idea that collaboration support tools could improve knowledge exchange processes in the organizations we looked at. In all three cases we ended up with much more specific support ideas that targeted certain weaknesses of the existing ecosystems. All three case studies highlight the importance of understanding the work practices of an organization to recommend and design technology. We do not argue that the two general approaches to design that we used are comprehensive and that they will cover all kinds of organizations and work practices. However, we do believe that small variations in these findings can be used to design technologies for other organizations. The important issues are how artifacts can be accessed, how they support the interaction among actors and how the dynamics of this relationship evolve—and how additional actors need to be integrated in the considerations of dealing with these dynamics.

6. Visibility of and access to artifacts

Artifacts do not represent static reality but are malleable and negotiable (Lutters and Ackerman 2002). As we see in the Document Focused Design case studies, documents meant different things to different people and held specific significance for particular groups based on their practices. For us one of the design challenges was to let users be able to do that but also be able to share documents. Also, we always have to be cautious that someone's critical document might not hold any value for someone else but we still need to include it in the system. Therefore, we avoided interpreting what exactly a document might mean to a certain actor and to specifically designing for that meaning. Rather, we supported different interpretations and multiple perspectives. For instance, 'Context Grabber' allows users to apply their own classification schemes because such flexibility can support human actors in structuring large collection of artifacts (Simone and Sarini 2001). As a contrast it is interesting to note the differences in the production of artifacts in the day-to-day work of the organizations; not just in terms of number but also in terms of medium. As more and more firms move towards a digitization of resources, the dynamics of knowledge ecosystem changes, the meaning of artifacts changes (they become more important for an expertise assessment of people), their visibility changes (ubiquitous visibility becomes possible, but it may become more difficult to retrieve the 'right' artifact), and actively addressing the knowledge sharing aspect is going to become critical.

7. Primacy of actors

As far as focusing on people we can do it in two ways: we can increase the awareness concerning a certain community as a whole and their interests and expertise or we can help people find specific others whom they can get in touch with when in problems. The first scenario is more about peripheral interaction and the other about direct information. We believe that each of these approaches has it advantages and when used in tandem these approaches can add a lot of value to an organization. The community approach gives people the opportunity to come together around an idea and maybe lead to new groups and projects. The individual worker approach avoids critical breakdowns within the organization. In another instance of work we have looked directly at how human actors can be "matched" based on documents that they create. We find that documents are a good indicator of people's interest and are often context-bound within organizations to be a good indicator of not only what people's interests are but also of what they are working on.

Inherent in our focus on people is a predisposition towards treating knowledge and expertise sharing as a bottom-up process, which precludes an analysis at the organizational level. Our findings indicate that knowledge and expertise are not held by the organization per se, but are a result of the interaction of artifacts and actors in activities. In some sense, for us an organization becomes an organization through the happening of these processes and practices. Artifacts are manifestations of what is "left" or "held" in the organization. However, their value is derived through artifacts in action and in use, not artifacts merely as stored. As we saw in the case of the Steel Mill, artifacts stored have little value if they could not be used by people in their practices and blended smoothly with the practices.

8. Oscillating duality in practice—and the third force

As in any living ecosystem, where the balance of organisms and non-living elements is crucial, in an organizational ecosystem the balance between actors and artifacts is important. Particularly within the context of knowledge and expertise sharing, this balance is needed: even when primacy is given to artifacts, interpretation still resides with actors, and actors' interpretation is dependent on their access to artifacts. We think that this focus on actors and their artifacts is a pragmatic as well as theoretically sound way of improving and enhancing knowledge and expertise sharing within firms. It helps us move beyond just focusing on either artifacts or actor and it encourages us to look at their interplay. In keeping with the metaphor of symbiosis, and the duality inherent in that metaphor, we believe that artifacts and actors can enrich each other and have a relationship that benefits both. This requires sustained effort and a lot of involvement and commitment. But, for the long term survival and growth of the ecosystem this kind of a relationship is essential. We as researchers and designers play the role of a catalyst in bringing about this symbiosis. We term this "oscillating duality" since inherent in this duality is the differential primacy of agency by artifacts and actors at different times (Figure 1).

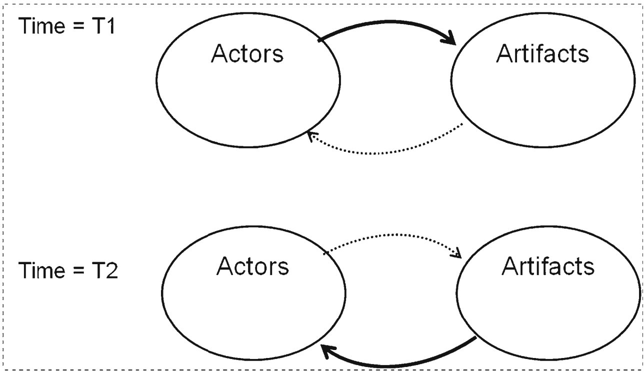

Figure 1. Oscillating duality of practice in an ecosystem.

Our studies also showed that there is, however, a third force that became an integral part of an expertise sharing ecosystem. While in biological ecosystems the interactions among the different life forms follows quite stable dynamics and slowly evolves over time, IT support in expertise sharing ecosystems tweaks visibility and access to artifacts as well as actors in such a significant way that the IT designers themselves have to be considered being part of the ecosystem.

All technological solutions we described emerged through an intense exchange of knowledge (about work practice and the associated knowledge sharing processes) between the designers and the users, and all of them required technological support and improvement until they were fully established. Decisions such as what information should be a part of a profile or on what ontologies are being used to describe expertise of individuals or to classify artifacts may have to be reconsidered frequently in that process of establishment.

In the SIGMA example, several attempts had been made to establish a Yellow Page system, but the final solution we offered avoided certain pitfalls of this approach and offered an emergent information system, in which the very definition of what 'expertise' is to end users could be reformulated. In the NIA case, users were able to influence the representation of their expertise by changing the sets of documents they provided to the system. And in the steel mill, the context grabbing application allowed to define own terminological contexts even for large groups of documents. In all these examples, the information systems remained configurable by end users. The users taking on these configurations became ecosystem gardeners, and form—together with the designers that are necessary to change more fundamental aspects of the ecosystem—a third force aside from artifacts and actors that are directly involved in knowledge exchange processes.

In a recent case we also described the role and importance of the IT support for communities with a discontinuous practice (Saeed et al. 2010). In the long-term study about the knowledge exchange processes around the organization of several conferences of the European Social Forum, the quality of IT support, and the access to the people responsible for it, heavily influenced the quality of knowledge exchange processes around organizing the conference.

9. Conclusion

Even though the present era has been dubbed the era of knowledge economy and knowledge society and there is an implicit and explicit understanding that knowledge work is the most important work that organizations do, a deeper investigation of any organization always uncovers some tacit dimensions of knowledge and expertise sharing that has gone unexplored with often disastrous consequences for work. The value of expertise and knowledge sharing practices is consistently undervalued even by workers who are best served by adopting and/or revising their practice (Groth and Bowers 2001). This lack of knowledge and expertise sharing awareness becomes even starker given the rise in use of information technology and recent products that claim to serve exactly that purpose by combining information sources and communication channels. We believe that the role emerging technologies have started to play lends credence to purposive knowledge and expertise sharing efforts, particularly when these efforts integrate artifact-centered approaches and people-centered approaches to support knowledge sharing processes in organizations. Furthermore, although we believe and acknowledge that generic versions of these approaches will work to a certain extent in any organization, it is highly beneficial to categorically examine work practices around knowledge exchange platforms and to support the activities we find there (Pipek and Wulf 2003).

We have analyzed and described two different approaches in which knowledge and expertise sharing can be supported depending on the practices of the organization and this can serve as a valuable analytical framework to direct and understand IT effort. We argue that knowledge sharing practices within organizations can be categorized broadly in two primary ways: (1) Practices where archives and documents play a primary role in the organization; (2) Practices where individuals play the primary role in knowledge and expertise sharing, either working with another individual or as a member of a community. Furthermore, recognizing that knowledge-representing artifacts are of central importance in organizations (Cabitza and Simone 2009) we further identify that there are two types of artifacts within organizations—artifacts that represent knowledge about a domain (drawings, slights, contribution to news groups) and artifacts that represent knowledge about human actors (yellow pages/directories). When working with artifacts for knowledge sharing, we uncovered several issues associated with knowledge representing artifacts that deserve special attention, such as, classification of the artifacts, interpretation of the content, and updating of the content. We showed how artifacts imbibe different values in different work settings and a central focus on how artifacts can structure information, people or community can help us design better expertise and knowledge sharing technologies.

The major innovation of the Answer Garden approach was that the role of maintaining an organizational memory (through 'gardening', e.g. creating and revising documents) was integrated with the role of providing expertise, making the system, ideally, a self-propagating and self-improving activity. In our long-term case studies we saw that various interests and conflicts of the actors involved complicate this situation. Within any organizational ecosystem, a delicate balance exists between diverse elements—people and artifacts—and any attempt that disrupts one element changes the ecology and consequently has repercussions throughout the ecosystem. The goal then is to channel this change-effect positively. Therefore, through our solutions we eased 'gardening' tasks with the 'context grabber' application at the steel mill; within the 'Expert Finder' systems we provided an easily configurable mechanism for self-representations of experts; and through the 'Expertise Awareness' application we provided a highly flexible solution that allowed continuous modification of indicators of expertise within an organization.

In each case our final solutions only vaguely resembled our initial ideas. As a matter of fact, certain aspects of our first ideas underwent significant revisions until final applications were created that could addressed perceived weaknesses of the existing expertise sharing approaches within the organizational ecosystem. Our design based research approach allowed us to understand and account for perceptions of all actors involved in the process, but it required a continuous collaboration with them. In essence, our team itself became a part of the expertise sharing activities within the ecosystem. This is not an insignificant observation as the role of designers and developers is often overlooked in explaining and accounting for changes due to technology introduction. System developers through their interaction with end-users themselves become a part of the ecosystem and change the ecological balance of the organization. This is true while design and user testing is going on but often becomes even more salient when that interaction ends, something which is commonly reflected in failure of new technologies due to lack of significant user base once technical support is withdrawn. Our work highlights this complex relationship between system designers and users to alert designers to be attentive not just to site access and user testing, but also to the manner in which they disengage with their user community i.e. leave the site of design and research.

To recall, here are the key findings of our study (Overview in Table 1):

(1) practice-oriented design inspired research methods lead to specific and innovative technologies for expertise sharing within organizational ecosystems;
(2) we need to integrate the new applications into existing ecosystems without disrupting the ecology, which can be safely accomplished by maximizing compliance with the technological infrastructures in place;

Table 1. Overview of case studies.

Approach	Artifact focused design	Actor focused design	
		Community-oriented	Individual-oriented
Description	In this approach artifacts, including documents and software code, are given primacy and the technology facilitates assignment of context to artifacts by workers.	In this approach the community of workers is given primacy and technology is designed to make coworkers aware of each other's expertise.	In this approach an individual worker is given primacy and technology is designed to support her need to find a coworker with a particular expertise.
Representative artifact	Document management	Yellow pages/directory	Expertise finder
Case study	Steel mill	Global consultancy	National industry association
Functionality designed	Context grabbing	Expertise awareness	Match making
Integration with existing technology	Side functionality for all tagging systems; integrated in an existing document management system	Via sensors measuring expertise-indicating events in (groupware) applications; separate monitor application	Input via Documents, autonomous recommender system
Role of researchers (Disengagement)	Software development, system administration, user support (on site, email, 18 months)	Software development, system integration, system administration, user support (on site, email, 2 months)	Software development, system administration, user support, (on site, email, 8 months)

(3) it is critical to examine the interaction between artifacts and actors within the ecosystem and design to balance their roles, which are often mutually intertwined (need each other), to maximize use in practice;
(4) it is important to acknowledge the link between domain knowledge (content) and knowledge for access (navigation);
(5) and, expert 'gardeners' (as the connecting role between users involved in creating knowledge artifacts and in exchanging knowledge and the actors involved in developing/maintaining technological parts of the ecosystem) as well as IT developers are part of the expertise sharing ecosystem we address.

This work has significant implications not only for researchers and system designers, but also for information managers who have to become aware of the technology as well as the people and practices of the organization to be able to broker a symbiotic relationship between people and technology.

In essence, after repeated failures in the field we have stopped regarding our work as researchers, software engineers and system administrators (we took over all these roles occasionally in the cases we described) as 'the introduction of new technology' and we now regard what we do as modification of existing technological systems within the ecosystem (see also Pipek and Wulf 2009). An ecosystem perspective is extremely helpful in recognizing the reasons for this—no novel technology or its application arena is a blank state, something has always existed before and is bound to shape new efforts. Of course, in all our cases we were working with already existing firms that had an installed base of IT and a significant lineage of work practices. In ecosystems that are being designed from the group up, disruptive innovation might play a positive role. Related to this outcome, is another important outcome which is regarding the scope of the changes we make in the ecosystem. Our work shows that even small enhancements change the structures of practice significantly. Furthermore, as Orlikowski (1992) points out, in the case of information technologies modification of technology are quite common after implementation as the materiality of information technologies—their digital nature—allows for more and faster mutations. As a consequence, these small modifications become increasingly common in both quality and quantity and are more likely to interact with the existing ecology. Therefore, we believe that studies of incremental modifications will play a very crucial role in our understanding of how technology interacts with organizational elements.

Cases of knowledge management applications highlight the role of information in organizations. But it is IT in general that substantially changed the dynamics of information exchange in organizations (speed, visibility, amount, presentation, timeliness, direction, control of information). It did so in the 90's by means of groupware technologies in organizations and it does so currently by means of 'social software' also between organizations and beyond classical work contexts in our everyday lives. The ecosystem metaphor from Biology/Ecology we used throughout the presentation of our cases also illustrates this growing complexity, but also carries with it the challenge of deciding on the right granularity of ecosystems to consider. It is implicit to the competencies, education and professional identities involved with technology development to focus on a software application as a solution to a problem these professions are not a part of. But the strict dichotonomy of 'users' and 'designers' is seriously challenged by our experiences, The decision to see 'designers' as a part of the system we are looking at when analyzing, performing or conceptualizing technology development activities is not an explicit, conscious one (as methodology names like 'participatory design' or 'user-centered design' imply), it is integral to the problem we are looking at (information flow), and to the material (software) we are working with. The ecosystem level we need to consider has to go beyond just looking at a 'field of application' of a software system, but also integrate all roles that contribute to the successful establishment of a technology usage.

This necessity is already visible in two recent trends. Evolving 'social software' systems as a combination of lightweight technologies with flexible inter-individual and inter-group information exchange practices beyond organizational borders on the one hand, and 'Open Source' ecosystems like Eclipse as an integrative development/communication platform for traditional 'users' and 'developers' on the other hand, point us at future possibilities of expertise and knowledge sharing systems (Adamic et al. 2008; Nam et al. 2009; Nett et al. 2008), and at the future of IT development as such. More targeted support for knowledge sharing in 'social software' systems (e.g. connected groups of experts on Yahoo, Facebook, and YouTube) with regard to strategies, providing (a) more or different 'knowledge artifacts' and (b) new communication channels to experts brings information and communication closer together. An integration of designer-designer and user-designer communication into the very tools, as demonstrated in the Eclipse ecosystem, reveals interesting design directions which systems for knowledge sharing could take. In addition, the changing context of work makes it extremely likely that the knowledge and expertise sharing practices span not just an ecosystem but an interacting network of ecosystems that extend globally. But although none of the organizations we studied was a global organization, it is not hard to see how this kind of expertise and knowledge sharing processes might be important for and hard to achieve in these kinds of organizations.

While the metaphor of 'ecosystems' helped us here to illustrate complexity and dynamics of technology support for knowledge management and sharing, the challenge to suggest alternative methodologies that reflect our considerations is still open. Building on Star and Ruhleder's (1996) 'steps towards an Ecology of Infrastructure' we (Pipek and Wulf 2009) started to develop a theoretical framework around the analysis and support of 'Infrastructuring' activities in technology design that we will further tailor to the specific challenges of Knowledge Management the experiences we described here suggest. The dynamicity of the creation of work practices to share knowledge through the appropriate adoption and adaption is also captured by the concept of 'socio-material bricolage,' the idea that workers successfully leverage the tools available to them to re-create their socio-technical practices (Johri 2011b).

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