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Designing a Knowledge Management Approach for the CAMRA Community of Science

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Abstract. CAMRA (Center for Advancing Microbial Risk Assessment) gathers a community of scientists that investigate several stages in the life cycle of biological agents of concern. This paper describes the knowledge management (KM) approach adopted for CAMRA's community of scientists. The approach includes knowledge facilitators, a web- and repository-based KM system, and use-centered design. The approach relies on a KM methodology that addresses the most common causes of failures in KM approaches that was complemented with a use-centered design methodology. The resulting combined methodology represents a unique way of implementing KM to promote knowledge sharing and collaboration. We describe the principles in our design and the initial steps undertaken to implement it for CAMRA. We conclude by laying out our future steps.

Keywords: Capturing and securing knowledge, Case-based reasoning, Collaboration, Human-computer interaction, Knowledge repository, Knowledge sharing, Web-based knowledge applications

1 Introduction

Knowledge management (KM) refers to the manipulation of knowledge assets as a means to improve organizational processes. KM approaches include the resources, methods, and instruments to deliver KM goals. CAMRA is a consortium of seven universities, including several investigators from each university. This consortium is an example of the model that government agencies are adopting for grant funding. This model makes knowledge sharing even more crucial than ever to guarantee meaningful results from the funding. One reason is that geographically dispersed investigators pose the need of support for remote collaboration. Furthermore, strategies to promote sharing and collaboration are the only guarantee that funds will yield the intended results, i.e., that the overall result is greater than the sum of its parts. Hence, the KM goals for CAMRA are knowledge sharing and collaboration.

The approach for CAMRA is based on a repository-based KM system, one of the main categories of KM initiatives [10]. Although this type of system has been around for decades, such as best practices and lessons-learned repositories, many of its implementations have failed to demonstrate success [28]. For this reason, several authors (e.g., [5], [11], [13], [21]) have investigated causes for those failures, suggesting failure factors for KM approaches. Based on these factors, a methodology that attempts to overturn the effect of those failure factors was proposed by Weber [26]. This methodology focuses on knowledge sharing with strategies being implemented both computationally and by knowledge facilitators. In pursuing a successful KM approach for CAMRA, we complemented these strategies with use-centered design. Use-centered design is a method from human-computer interaction (HCI), a field that focuses on the user perspective.

The next section describes common failure factors in KM systems, followed by the resulting principles we adopted in designing the KM approach for the CAMRA community of scientists. In Section 3, we describe the use-centered cycle and, in Section 4, we describe how we implemented it. In Section 5, we conclude and present plans for future work.

2 Overcoming Failure Factors for KM Systems

In this section, we indicate the areas where failure factors most commonly occur and then describe the principles in our KM approach. There is not a perfect correspondence between failure factors and principles because factors originating in technology may be addressed with human participation and vice-versa.

2.1 Failure Factors

A general cause of failure in KM approaches has been proposed by Abecker, Decker, and Maurer [1]. Approaches that do not integrate humans, technology, and processes are likely to fail [1]. Another general cause of failure was suggested by the difficulty in measuring knowledge [3], which makes it difficult to measure knowledge sharing. The failure factor stems from the lack of trust in endeavors that cannot demonstrate their effectiveness.

Failure and success of organizational efforts are strongly influenced by management actions. Marshall, Prusak, and Shpilberg [18] introduced a series of responsibilities community leaders must exercise with respect to knowledge creation. Holsapple and Singh [17] group those responsibilities into four categories: leadership, control, coordination, and measurement. These relate to the key elements (humans, technology, processes, and evaluation) described above. The key leadership practice when implementing a KM approach is to support it [11]. Skepticism is easily spread to all community members [19], particularly if it comes from the leaders.

Repository-based KM systems were originally adopted after the purchase of text database systems [10]. However, long texts are time consuming to read and may be difficult to interpret [4][27]. Moreover, free text typically lacks (or hides) essential elements that constitute a knowledge artifact, thus only information can be shared. The field of knowledge engineering has several decades studying methods to represent knowledge. Their absence is likely to prevent knowledge sharing.

The design and integration of KM systems is another determining element in knowledge sharing. KM systems that are not integrated into the community processes pose several problems [6][24][27]. Standalone systems that rely solely on pull methods are generally less effective since they rely on users to initiate search behavior, what may be prevented due to several reasons [27].

It is through collaboration that humans typically share. A KM approach has collaboration as an implied goal because it is a condition that promotes sharing while sharing also encourages collaboration. Transparency is an essential element for collaboration [23], thus lack of transparency tends to hinder knowledge sharing.

A well-known failure factor in repository-based KM systems is the difficulty to motivate members to contribute artifacts. For many workers, contributing to a KM system adds an additional task to already tight workloads. Community members do not typically find they are properly compensated for the time allocated to submitting knowledge. Incentives from leaders and the participation level of other community members both influence users' perceived payoff [9]. Furthermore, when members contribute artifacts, they are exposing themselves to the community. Their contributions may be perceived as extreme in some dimension [11]. This suggests that communities that are not culturally tolerant are more likely to discourage sharing thus favoring failure.

Recognizing the community's culture is crucial. Therefore, KM approaches that ignore the targeted community culture are very likely to fail. All categories of stakeholders have something to contribute and so do all community's processes. However, simply targeting a community by building a monolithic organizational memory is also prone to failure [2].

Among studies on impediments to knowledge sharing, Szulanski [25] presented four important impediments that constitute failure factors. Two impediments relate to incompleteness. The first refers to the limitation of an artifact that is created from one originating event only. The second is the lack of facts that validate the quality of an artifact. The two other impediments are caused by the user who accesses an artifact and with whom knowledge is supposed to be shared. The third and fourth impediments occur when the user is not sufficiently knowledgeable of the subject matter. This user will have limited conditions to absorb and then to retain shared knowledge. Szulanski [25] refers to these two last impediments as lack of *absorptive* and *retentive* capacities.

2.2 Principles in Designing the KM Approach

The design principles in our KM approach are based on the general strategies described by Weber [26], implemented both computationally and by human facilitators. One distinguishing element of the approach is its targeted community.

2.2.1 The Targeted Community of Science

We propose the term *community of science* (CoS) to describe a group of scientists that is joined by a research project or department, who share the same goals as defined by their common project or department. Because junior scientists are supervised by a senior member, addressing their needs is not contemplated by the approach but by their supervisors. Examples of a CoS are investigators that are funded by the same grant and faculty in the same department. Although their background interests may be multidisciplinary, their goals are intrinsic to the grant or department they belong.

A CoS shares similarities and differences with *communities of practice* [29]. Communities of practice (CoP) unite members because of a common topic or practice [15], tending to be permanent. A CoS unites a group of members who are research scientists and are united by the goals of a grant or employment in a department for the duration of the relationship.

A CoS also shares similarities and differences with *communities of interest* [5]. When defined in the context of design tasks [5], communities of interest (CoI) are interdisciplinary groups that are united for the duration of a specific project or task [15]. Nevertheless, the web has adopted a looser connotation for CoI as a group that is united by a common interest. This is observed by the solicitation of members to join communities of interest and the definition in Wikipedia: "*A Community of interest is a community of people who share a common interest or passion*[1]".

Although sharing the temporal characteristic of the first definition of CoI, a CoS has exclusive characteristics that make it unique when designing a KM approach to support it. They have innovation as their role in science, becoming culturally tolerant to criticism when members expose themselves trying to share knowledge. The cultural practice among members of CoS is to be reviewed by their peers, which organizes them in flat hierarchies, making them culturally adequate to accept and support KM activities [26]. Members of a CoS are motivated to share their findings, making it easier to encourage them to do it in a systematic way. Further studies on the associations between CoI, CoP, and CoS are needed.

2.2.2 Technological Principles

Technology is utilized in the development of a repository- and web-based KM system. The most important concept in our design is the knowledge artifact we tailored for the CoS. We wanted to ensure that the repository retained knowledge artifacts and not information artifacts. A knowledge artifact must include the minimal elements for a user to make a decision to solve a problem, and be easily interpretable [4]. Otherwise, an information artifact distributes information and the user has to rely on his or her own knowledge to make a decision, producing inconsistent results for the community. Furthermore, knowledge artifacts should adopt a knowledge-based representation formalism. Weber and Aha [27], motivated by the definition of lessons-learned, proposed

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[1] Retrieved on 2 October, 2006, from http://en.wikipedia.org/wiki/Community_of_interest

a knowledge-based representation for knowledge artifacts. Such representation allows the adoption of the case-based reasoning methodology for retrieval and reasoning.

This representation consists of two indexing elements that allow the assessment of when an artifact is applicable; and two reusable elements. Indexing elements are tasks or processes, and state variables describing the context of applicability of the artifact. The reusable elements are the core of the knowledge artifact, i.e., the strategy that will enable a decision to be made to solve a problem; and the fact that substantiates its validity.

For a CoS, we tailored this knowledge artifact and call it a *learning unit* (LU). In its origin, it is similar to a lessons-learned, but its elements are associated with processes typical of a CoS, e.g., research contributions. LUs have four core elements: 1) *Research Activity* is the activity a user is to be performing for the artifact to be useful. 2) *Contexts* are the conditions that determine that the artifact is applicable for the research activity. 3) *Contribution* is what was learned from performing the research activity. 4) *Rationale* refers to a supporting evidence for the contribution.

LUs are objective, explicit, and easy to interpret. They make the knowledge of a member easy to understand and interpret. This transparency promotes collaboration [23]. LUs are meant to be exchanged among scientists that are members of a CoS. They are not meant to be used to communicate scientific advances to the public in general.

LUs allow the system to manipulate research contributions for the creation of performance reports. Thus, we are currently testing the design of reporting tools in order to offer an explicit compensation as an incentive to users to allocate time to contribute LUs. Reporting tools for a CoS are particularly attractive because scientists are asked to report about their work on different formats, usually with the same contents. The commitment to the community members is they only need to communicate things to the system once.

The benefit of using this representation for knowledge artifacts is that LUs can be retrieved under the case-based reasoning (CBR) paradigm, in a fashion that resembles the way humans find relevant artifacts. In CBR, cases represent problem-solution pairs, thus case retrieval aims at finding a similar problem with the purpose of retrieving a useful solution. In a LU, a problem is described by a research activity plus its context. Thus, searching for a relevant contribution is about finding units that have the same or similar research activity, having contexts as a secondary attribute. For example, in the context of scientists working with microbes from different perspectives, finding all contributions that relate to the same microbe (e.g., *E. coli*) are likely to produce less relevant results than finding contributions describing the same research activity the scientist is current involved (e.g., modeling microbial fate). Typical keyword search methods, for example, would include this paper in the results for *E. coli*.

2.2.3 Human Principles

In designing our approach, human facilitators are responsible for complementing and compensating for the limitations of technology. They also play the role of mediators to help enforce managerial responsibilities. They educate users about the need for KM, the goals of the approach, and the technological principles. Knowledge facilitators help community members understand what knowledge will be useful and at which level of specificity serving as a mediator for integration. Knowledge facilitators review submitted LUs to verify compliance with the four core fields, so that they will keep the characteristics that result in benefits to the community. When interacting with community members, they discuss the KM system collecting feedback and suggestions.

3 Designing a Usable KM System

The principles in the last section are still short in fully addressing the human failure factors. Since our KM system is designed for humans to enter and retrieve artifacts, we must consider how it can be designed to be easy to use while supporting the goals and tasks of its users. Several authors (e.g. [22], [24], [30]) have suggested that knowledge management efforts are more successful when the system is initially designed with the users in mind. We also need a method to guarantee that the design process will include all the CAMRA stakeholders. Since we needed to strengthen our focus on the users and stakeholders, we included user- and use-centered methods from HCI targeted at helping us reduce difficulties that may be encountered by the users of our KM system.

3.1 User-Centered Design

As early as 1986, Norman and Draper [20] defined the user-centered design process for software applications. They suggested that users can be more successful with software if their needs are placed at the center of the design. Other practitioners and researchers have continued to define this concept and some key principles have emerged. Hix and Hartson [16] summarize two of these: understand the characteristics of different types of users and their tasks, and get actual future users of the system involved as early in the design as possible. Prototypes are commonly used in user-centered efforts to provide a common ground through which designers and users can communicate.

3.2 Use-Centered Design

We argue that a user-centered approach is necessary to the deployment of successful KM systems, but that it is not sufficient. Deploying a successful system requires a deep understanding not only of the application domain, but also of the practice of the people who will use the system [8]. In order for useful systems to be built in these conditions, system design must be based on a process of mutual education [12] between system builders and users. In other words, we must center not on *users*, but on *use* [7].

The goal of mutual education is to allow all members of the design team to contribute their expertise to the system building process. The most important resource in the system building process is an artifact that all stakeholders can understand and contribute to, and which serves to build a sense of community among the stakeholders.

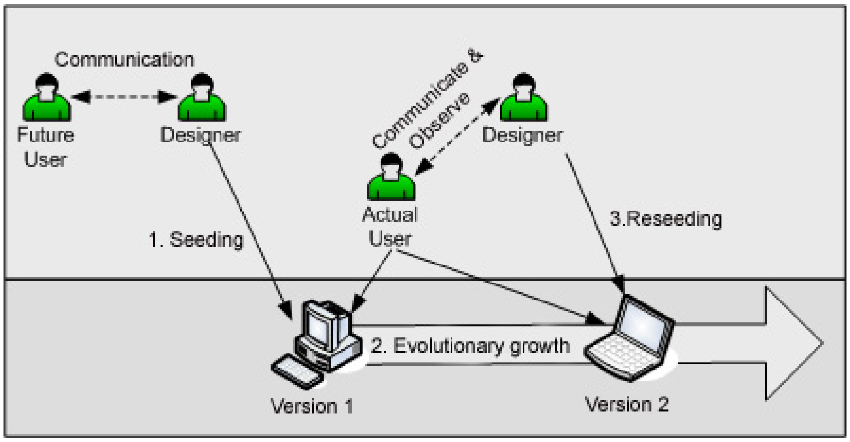

Figure 1. Use-centered cycle

To do this, we propose an evolutionary model of software development in which the expected utility of a system is improved by active, computer-based support for 1) feedback from users of prototype systems to developers, 2) communication and collaboration among users and developers, and 3) mutual education among user and developer communities. An overview of this "seeding, evolutionary growth, reseeding" cycle [14] is shown in Figure 1. Working with users, the design team (which include knowledge facilitators) develops an initial prototype for the system, which is then seeded into the use environment. Over time, as this prototype is used, new uses are noted and new ideas emerge. These are incorporated into a subsequent prototype and this seeding, evolutionary growth, reseeding cycle continues. The key to making this process succeed is recording the intent of design decisions and then observing how well actual use matches that intent. We call this technique *design intent* [7].

4 Implementing Use-Centered Design for CAMRA's KM System

The sections below describe the use-centered steps taken in the design and refinement of the KM system, being developed for the CAMRA community.

4.1 Seeding: The Initial Design Process

Before any actual user interface design began, we met with CAMRA scientists and collected user requirements for the system. The information from these early visits also provided us with a basic understanding of the user community that helped guide our early design efforts. We then used a paper prototyping process to develop the initial user interface screens. The team was able to meet with many members of the community during a project kickoff meeting, which provided the opportunity to demonstrate the user interface and to collect preliminary usability data based on common usage scenarios.

4.2 Evolutionary Growth: Findings from Reviewing the Paper Prototype with the CAMRA Community

At the kickoff meeting for the CAMRA project, all users were presented with an overview of the purposes and high-level design concepts for the repository. However, as we began walking the users through the paper prototype, the system became *real* to the users, since they were shown the system in the context of actual tasks they would be expected to complete. This process revealed a number of design challenges and user concerns about the use and purpose of the KM system that might have otherwise gone undetected until after the system was deployed, and we have already implemented changes to overcome the issues that were raised. We were also able to gather some information about the work practices and mental models of the future users of the system.

4.2.1 Entering Learning Units

The main function of the system is the ability to document scientific advances through LUs, which represent single pieces of knowledge that can be shared. We realized early in the design process that it would be critical to make the LU entry process as easy and efficient as possible.

According to our original concept, there are three different types of LU. *Findings* units were meant to store the knowledge obtained by experimental work conducted as part of CAMRA. *Ongoing* units were to be submitted during the research activity. Units labeled *Literature Review* were designed to collect contributions from published literature.

As we presented the original design for the LU screens, it became immediately apparent that while users grasped the general idea and purpose of a LU, they struggled to understand the distinctions we were making between the different types of units as well as between the four core fields that make up the key information in each unit. In some cases, the fields in the types Ongoing and Findings strongly reminded users of the sections of a research paper (i.e. task, results, conclusions, etc.), and they kept trying to match the required fields with that model. The Literature Review label also created some confusion, since it reminded some users of the research activity of analyzing broad sets of published literature, rather than the collection of specific background and prior research.

We addressed this problem by adopting a plain English approach to the types of LU and to the labels displayed in the user interface. For example, *Research Activity* became “What is the general research activity?”; *Contexts* became “In what contexts does this activity occur?”; and *Contribution* became “What is the contribution you learned?”. Another confusion we addressed was the field *Rationale*, which seemed to users to support the research activity, rather than the contribution of the unit. Therefore, we adopted “Summarize your results” to ask for the results that validate the contribution. The three types of LUs were re-titled and became “Things I have completed,” “Things that are in progress,” and “Things I have read.”

In our original design, we asked for the contribution and then for its justifying results. During the prototype review, the CAMRA scientists commented that they expected to enter results first and then the contribution since this is how they are used to describing their work. We revised the design accordingly.

4.2.2 Sharing Learning Units of Interest

Our approach includes two distribution methods: push and pull. We implement push via active casting [28] with our recommendation system. The system asks the contributor of a LU to identify users who might be interested in receiving a notification about the new LU. These users are then notified by email about the new LU.

Initial user response to this feature has been positive, although the success of these notifications depends on the contributor’s ability to know what types of interests other community members possess. For this reason, we incorporated research activities of interest to users in the list of users shown when the link *Find Users* (Figure 2) is clicked. Furthermore, users also suggested the inclusion of a customization option to enter research activities and contexts of interest so that units containing those would be cast to them. This way they would not have to depend solely on the choice of the unit contributor.

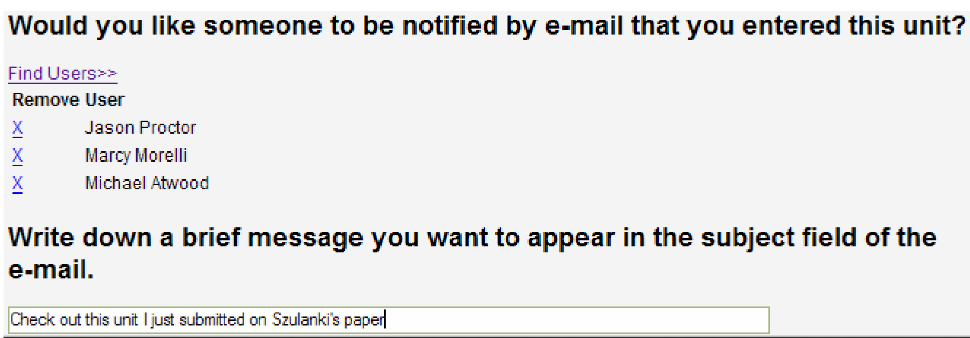

Figure 2. Users can type a subject line when recommending learning units

Users also suggested having the option to type a personal subject line to appear as the subject line of the email (Figure 2). This feature will personalize the message, helping the user receiving the notification distinguish it from other messages.

The pull method of distributing LU takes advantage of the representation that is amenable to retrieve units using the case-based reasoning paradigm, as previously explained. Although mostly only the research activity and the contexts are indexing components, aspects from the results or contribution may also be used to assess the similarity between an activity being searched and stored units. In fact, users requested for a comprehensive keyword search capability as well. For example, they would like to be able to find all units that reference a given author under *Things I have read*.

4.3 Reseeding: Matching the Design to the Practice

The CAMRA community is already using the first release of the system, but our design efforts do not end. As the system is used, we expect the work practices of the users to change. While most design efforts stop once the system is delivered, we argue that the most important design decisions are made after the initial delivery. For this reason, we are using design intent to monitor any changes in practice that should result in redesigns. Human facilitators are meeting with users from the community to guide them on how to use the system and to collect relevant feedback.

5 Concluding Remarks and Future Work

The experience in designing and developing a KM approach as we describe in this paper is unusual in many aspects. We refer to communities of science that have specific characteristics that are not shared by CoP or CoI. The CAMRA community is an example of a CoS, which has advantages of being supportive of innovation, being flatly organized, and for its tolerance to positive criticism.

One of the ways we will evaluate the CAMRA knowledge repository is by observing associations. After a member associates a new unit with an existing unit authored by a different contributor, he or she is asked to explain the nature of the association. Members are oriented by knowledge facilitators to seek for associations that require their expertise to be recognized and explained. If the member who describes the association did not know about the existing unit before that session, then the assumption is that knowledge sharing took place, i.e., knowledge from the existing unit was transferred to the contributor of the new unit. However, it is possible that this member has heard about the work on the existing unit by other means, preventing us from concluding knowledge sharing from the association. Thus, we plan to ask members whether the association step caused knowledge to be shared.

Another situation where we can ask members whether knowledge was shared is when a contributor notifies other users of a new unit. In the first stage, the member who has been notified has to actually click to read the new unit. Secondly, after some time, a pop up window can ask this member whether knowledge sharing has occurred. This alternative will require us to determine an amount of time that is acceptable for one to understand a unit. Additional evaluations of this system confirming its ability to overcome failure factors will include formal usability tests, analysis of usage logs, and interviews and surveys of system users.

We are currently undergoing another stage of reseeding that will produce another version of the tool. This next version will incorporate the two capabilities to find units and reporting.

Acknowledgements

This work is supported in part by the U.S. EPA-Science to Achieve Results (STAR) Program and the U.S. Department of Homeland Security Programs, Grant # R83236201. The authors would like to thank CAMRA community's members, who have provided constructive feedback as part of the system design process, PAKM 2004 reviewers, and Mr. Nicholas M. Sillik, our programmer.

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