Addressing Failure Factors in Knowledge Management

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Abstract. This article describes a knowledge management (KM) approach conceived from countermeasures targeted at addressing failure factors suggested in the literature. In order to counteract failure factors, the approach combines the technology of knowledge-based KM systems, with the flexibility and understanding of knowledge facilitators, and the processes of the target community. In the KM system, the approach uses knowledge engineering concepts to represent knowledge artifacts and to enforce managerial responsibilities. By imposing a strict representation format, the approach guides and helps users. It does so by determining what knowledge to contribute, by enabling knowledge collection, and by representing knowledge. The purpose of knowledge facilitators is to complement the limitations of the computer-based component by verifying the quality of submitted artifacts and by motivating members to adopt the system. The design and operation of this approach is guided by identifying the processes of the target community and the level of specificity where they are useful. The importance of this contribution is that it offers guidelines to design a KM approach that relies on conclusions from published literature. In addition, it also proposes a means to validate knowledge sharing. A conclusion of this work is that it may be easier to address failure factors of KM approaches when all members of the target community have the same technical goals, are motivated by a common interest, are organized on a flat hierarchy, and are receptive to innovation. In addition, the use of a representation of the community's processes helps standardize capture, guide contributors, and associate existing with new artifacts. This association of artifacts can be used to validate knowledge sharing.

Keywords: Architectures for knowledge management systems, case-based reasoning, community of science, knowledge management systems, knowledge repository, validation.

1. Introduction

While general management is concerned with physical and human resources, knowledge management (KM) refers to the allocation of knowledge assets as a means to improve organizational processes. KM approaches include the resources, methods, and instruments to deliver KM goals. KM goals are usually described in terms of knowledge assets. Due to the nature of knowledge assets, organizational processes tend to improve as knowledge assets are shared and leveraged among organizational members.

In this article, we focus on repository-based KM approaches, one of the main categories of KM initiatives according to Davenport and Prusak (1998). Although this type of approach has been around for decades, e.g. lessons-learned systems, best practices (Weber, Becerra and Aha, 2001), many of its implementations have failed to demonstrate success. For this reason, several authors (e.g., Quinn et al., 1996; Fahey and Prusak, 1998; Disterer, 2001; Atwood 2002) have investigated causes for those failures, and have suggested failure factors associated with KM approaches. However, the literature fails to provide a method that explicitly takes a set of those failure factors as its basis. This article attempts to fill that gap. We examine this literature, and in Section 2 we summarize the fifteen failure factors we address in our method.

This article's intended contribution is to review and extend previous work on failure factors and to recommend countermeasures that a KM approach should utilize in order to prevent failure. The guidelines in Section 3 are the basis of our proposed KM approach. They may be recommendations for additional or alternative resources or methods, or they may designate constraints.

In Section 4, we describe an ongoing implementation of our approach to manage knowledge for a community of scientists. We conclude in Section 5.

2. Why do KM systems fail?

Previous literature indicates many potential reasons for KM approaches to fail. We list and briefly summarize several of these reasons that cause KM approaches to fail. Rather than an exhaustive review of the literature, we highlight the main areas where failure factors have been suggested. We also include a few failure factors that are relevant for KM systems either because of its learning aspect (number 5) or because of its nature as an information system (number 3).

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1. *KM approaches may fail when they attempt to create a monolithic organizational memory*. Organizations that tried to develop a monolithic organizational memory for an entire organization have failed (Ackerman and Halverson, 2000). Among other reasons, such organizations are distributed and may have conflicting goals.
2. *KM approaches may fail when they do not integrate humans, processes, and technology* (Abecker, Decker and Maurer, 2000). This is justified by the limitations and importance of each of these components. Humans alone are slow and have limited capacities. Processes are the main component in delivering organizational goals. Thus, any approach that is not associated with processes will tend to fail or to be perceived as failures. Technology cannot be considered alone, it is limited to supporting humans because of its variable accuracy levels when performing simple mundane human tasks.
3. *KM approaches may fail when they are designed without input from all stakeholders*. This happens when systems analysis and design ignores the community processes and organizational culture. This is very likely to increase resistance in adoption of the approach. This is considered a failure factor in the development of any systematic approach.
4. *KM approaches may fail when contributors do not know the ideal specificity of knowledge*. There is a level of specificity that makes knowledge worth transferring. Contributors may not know the level of generality that would make knowledge useful (Disterer, 2001), causing them to submit useless artifacts or not submit anything at all.
5. *KM approaches may fail due to lack of leadership support* (Disterer, 2001). Sometimes community leaders are not convinced of the benefits of knowledge sharing (Nonaka and Konno, 1998), potentially spreading their skepticism to the community.
6. *KM approaches may fail when users are afraid of the consequences of their contributions*. This cause is related to job security. Contributions from a member may be subject to criticism (Disterer, 2001) or evaluation (Weber, Aha and Becerra, 2001); they may oppose content already captured (Atwood, 2002); users may even feel that withholding their knowledge may be a way to secure influence (Disterer, 2001).
7. *KM approaches may fail when they store knowledge in unrestricted textual representations* (Weber and Aha, 2003). Knowledge artifacts stored in textual format may be long and difficult to interpret. This makes the recognition of the usefulness of the knowledge artifact a time consuming and maybe impossible task. Textual formats may also lack social and process context (Atwood, 2002).
8. *KM approaches may fail when they rely on inadequate technology*. Davenport and Prusak (1998) describe how repository-based KM initiatives started when many companies purchased text databases. The limitation of this technology to support KM has been discussed by McDermott (1999). Nissen (2002), states that this problem originates because these tools only deal with data and information, they do not manipulate knowledge, as required in KM approaches. A further of example of limited technology can be found in the interfacing between system and users. Humans use natural language to submit knowledge artifacts when interacting with a computer tool that is limited in its ability to understand (e.g., Lester, Branting, and Mott, 2005) the captured artifact. The verification of knowledge artifacts requires interpretation, what is neither precise nor easy. Therefore, if the submitted artifact is incorrect, the tool may not be able to determine that and guide the user.

1. *KM approaches may fail when they are outside the process context*. Weber and Aha (2003) attributed failure in the dissemination role of repository-based systems to their standalone design housed outside the environment of the target processes where users are to reuse knowledge artifacts. The authors claim that there are various implications for the user. The users have to know the repository exists; to have time to open and search it; to have the skills to use it; to know where to access it; to believe that the repository contains useful knowledge; to believe that knowledge reuse is beneficial. A further problem with tools that are outside the process context is that they force the user to divert from their normal activities (Atwood, 2002).
2. *KM approaches may fail when they ignore impediments to knowledge transfer*. Szulanski (1996) has studied impediments to the transfer of best practices that also suggest failure factors. One impediment is that knowledge to be transferred typically cannot effectively communicate the factors that make a strategy applicable to different situations. Consequently, potential re-users do not know how to extend it to different contexts. Transfer may also be hindered when knowledge does not include a description of how it was learned (*unprovenness*). Potential users

may also lack *absorptive* and *retentive capacities*, which may originate from the lack of understanding of the subject matter.

3. *KM approaches may fail when they do not enforce managerial responsibilities* (Weber, Breslow and Sandhu, 2001). Marshall, Prusak and Shpilberg (1996) list these responsibilities as follows: determine knowledge, enable knowledge collection, represent knowledge, embed knowledge in targeted processes, verify and validate knowledge, oversee knowledge reuse, monitor knowledge transfer, and create infrastructure for the preceding responsibilities. It is easy to envision how an organization that does not enforce these responsibilities can have no control over knowledge being shared or reused. It is likely that such individuals may not be contributing to organizational goals. Ignoring these responsibilities may also promote incoherent paradigms (Disterer, 2001) which may leave contributors with knowledge that does not contribute to organizational goals.
4. *KM approaches may fail when they do not properly oversee the quality of stored knowledge*. This factor is an ensemble of issues. It is part managerial responsibility (Marshall, Prusak and Shpilberg, 1996); it also relates to the representation of artifacts in an understandable manner (Weber and Aha, 2003).
5. *KM approaches may fail when they do not promote collaboration*. Collaboration is an important means for learning and sharing. Therefore, any KM approach that does not promote collaboration is likely to fail.
6. *KM approaches may fail when they are not able to show measurable benefits* (Alavi and Leidner, 1999). Unfortunately, many KM systems fail to demonstrate their effectiveness, which is a requirement for any business (Ahn and Chang, 2002). In some cases, the problems originate in the organizations, in others in the technology.
7. *KM approaches may fail because users do not perceive value in contributing.* KM approaches do not typically offer any reciprocal value to compensate for the time allocated for knowledge sharing. Hence, contributors may not perceive any value in contributing, to themselves or others (Disterer, 2001).

3. Guidelines for KM approach

The many causes of failure of KM approaches appointed in the literature can be used as a basis to guide an approach to prevent failure. In this section we discuss countermeasures to address the failure factors discussed in Section 2. These countermeasures represent functions of a KM approach, which can be delivered either through a technological component, i.e., KM system, or through knowledge facilitators, or they may suggest a target community or organization may be at risk of failure. They are combined into guidelines for a KM approach with a greater potential for success. These guidelines are sometimes difficult to implement. Section 4 illustrates their implementation with an example community.

1. *KM approaches should be designed to support communities of practice.* The goals of the target community should be assessed in order to determine if it represents one single community of practice, or if it should be subdivided into sub-communities. Being a community of practice implies that its members share the same interests. Sharing same interests allows for consistency in the quality of knowledge artifacts as the artifacts are geared to positively impact the same target processes. This concept may also be extended to a community of science, where its users share the same scientific goals in a common field of study.
2. *KM approaches should integrate humans, processes, and technology*. The human component should consist of knowledge facilitators and users (i.e., knowledge workers) who work together to understand the community processes, and master the technology. The processes that are relevant to the target community should be identified and incorporated into the main steps of design and development of the KM approach. The KM system should incorporate the community's processes, and be designed with user's input.
3. *KM approaches should be designed in collaboration with different stakeholders*. Designers and stakeholders together can perform a thorough analysis that takes into account the context of the processes of the target community. Analysis and design should be initially based on the elements derived from this study of countermeasures. Once they are explained to stakeholders and the main principles of the basic design are understood, other aspects should be discussed within the context of the processes that are relevant to the target community. Particular importance should be given to performing analysis and design within their organizational context (Atwood, 2002).

4. *KM approaches should identify an adequate level of specificity*. The level of specificity to be adopted should be considered useful by the majority of the users. Identifying a useful level should be part of the analysis of the domain. The level of specificity should be constantly monitored by knowledge facilitators as new knowledge artifacts are captured.
5. *KM approaches should be strongly supported by the leaders of their target communities.* If the targeted community cannot count on strong leadership support, knowledge facilitators should educate its leaders on the expected benefits of the KM approach. Management should contribute financially (Whiting, 1999) and understand it as an investment; promoting the success of the approach as return on the investment. Once they understand the benefits, leaders should become role models in knowledge sharing (Quinn, Anderson and Finkelstein, 1996). The need for leadership support suggests better results when implementing the KM approach in a community with a flat hierarchy, whose leadership is at a level that is not too different from its members. Knowledge facilitators should warn leadership of the risk of failure due to lack of their support.
6. *KM approaches should be adopted by communities that encourage innovation*. Communities that encourage innovation and positive criticism, where competition and job insecurity do not prevent sharing are ideal for successful KM approaches. However, if criticism is a strong element in organizational culture, then a KM approach should attempt to limit the scope to a community or to a set of processes where innovation and criticism are justifiable and used to commend, rather than to eliminate members. Knowledge facilitators and leadership should discuss how to support innovation and how positive criticism can motivate contributions and how the opposite will render their investment useless. Organizations whose culture is not sufficiently open to change will be at risk and thus leadership has to be oriented to acknowledge this risk.
7. *KM approaches should adopt representations with set of specific fields*. A small set of fields will guide and restrict users, creating short and focused representations that will make it easier to bring context and to help recognize an artifact's usefulness and applicability. As we will discuss again under Guideline number 1, it helps interpretation and provides context if one of these fields is utilized to represent the process the artifact can influence. An industry conceived knowledge artifact that identifies the process where it can be applied is a lesson-learned (Weber, Aha and Becerra, 2001). In order to meet all requirements imposed by its definition, a representation for lessons-learned should highlight the process it impacts, its validation, applicability, and the lesson it teaches (Weber, Aha and Becerra, 2001). Representations that are easy to interpret also facilitate transparency.
8. *KM approaches should adopt technology only when it is suitable for a task*. When technology is not adequate for a task and a suitable one is not available, then this task should be left to humans. For example, information management tools that deal with data and information should not be used to represent knowledge artifacts. Knowledge engineering (Liebowitz, 2001) is the field dedicated to the study of knowledge-based methods (Nissen, 2002) where knowledge formalisms are used to represent and reason with knowledge (not data or information). Natural language processing is usually computationally expensive and still prone to error (Brüninghaus and Ashley, 2001; Crysmann et al., 2002). For this reason, knowledge facilitators should be responsible for verifying the appropriateness of submitted knowledge. Weber and Kaplan (2003) categorized KM approaches based on the type of technology, referring to approaches that rely on knowledge-based methodologies as knowledge-based knowledge management. They explain why knowledge transfer is facilitated when proper knowledge-based methodologies are adopted. The recommended knowledge-based technology for implementing KM systems, according to several authors (e.g., Althoff and Weber, 2006; Watson, 2003), is case-based reasoning (CBR). In CBR, knowledge is experiential and it is represented in a case. Cases include indexing and reusable components. Weber and Aha (2003) adapted a representation for lessons-learned based on cases. The indexing components include an activity or process and information about the context. The activity is where the lesson is applicable, while context provides the circumstances in which the lesson was learned. These two indexing components help retrieve artifacts that are applicable to a task when similar circumstances are present. The reusable components include the central strategy taught by the lesson and a lesson rationale that explains how the lesson was learned. This knowledge representation incorporates all the elements necessary for applying a strategy and reasoning; it does not simply manipulate data and information.
9. *KM approaches should be integrated into the context of target organizational processes*. The context where members deliver organizational processes is where knowledge artifacts are to be

shared and are potentially reusable. Therefore, all knowledge artifacts must explicitly indicate the process they can impact. When knowledge artifacts are to be reused in the context of a computer system, then the *monitored distribution approach* (Weber and Aha, 2003) can be implemented for proactive distribution (i.e., a process-based push method) of knowledge artifacts in the context of organizational processes. Proactive distribution requires the use of an automated tool (e.g., ERP systems) for delivering user's activities. When this is not the case, then active casting can be used to push knowledge artifacts based on user's areas of interest. Pull methods should always be available to all users.

10. *KM approaches should include methods to overcome impediments to knowledge transfer*. Implementing effective methods to counteract Szulanki's (1996) impediments in his terms may not always be possible. For example, it may be too much to expect that contributors describe a knowledge artifact, including the factors that associate the strategy with the original context, and how the strategy should change when applied to different contexts. For this specific challenge, we observe that the inclusion of these additional contents would be more easily captured as additional artifacts. Therefore, KM approaches may target the building of comprehensive repositories with a dense coverage of strategies and contents, as long as relevant to its targeted community. Those repositories would include adjacent contexts eliminating the need for explicit descriptions of how strategy and solution relate. When making knowledge artifacts available to users, such as when users search for artifacts, closely related artifacts should be made visible to users so they may be able to infer how to adapt closely similar artifacts. The use of the CBR methodology may also address this problem with adaptation knowledge (Lopez de Mantaras et al., 2006). Moreover, some maintenance methods defined for CBR (Smyth and McKenna, 1999) utilize techniques to estimate coverage that can be used to determine which additional artifacts should be added to create a dense repository. *Unprovenness* can be addressed by requiring the inclusion of evidence or a description of how the strategy was learned in the artifact representation. In order to address both *absorptive* and *retentive* capacities, users of the system should be knowledgeable of the processes, so they understand how to absorb and retain new knowledge. This is a constraint imposed on the target community: when knowledge workers are ignorant of the domain such that those capacities are limited, then any KM approach is at risk.
11. *KM approaches should incorporate means of enforcing managerial responsibilities*. Actions to enforce managerial responsibilities should be incorporated into the design, training, and operation of the KM approach. The design of the approach should incorporate knowledge that is relevant to the processes of the target community: collection, verification, and monitoring. It is not the responsibility of the knowledge workers using the KM system to oversee the proper collection and verification of knowledge they have contributed. Those managerial responsibilities are requirements of the KM approach, and thus must be delivered within system design or through knowledge facilitators. For example, an interface to capture knowledge artifacts should be focused on the fields that can retain essential elements of knowledge sharing (e.g., reusable strategy, conditions that make it applicable). The infrastructure is to be supported in different ways by the KM approach. Knowledge facilitators should create tutorials and workshops to train users on how to submit artifacts using the KM system capture interface, which has been tailored to enforce an adequate representation to the community. Knowledge facilitators should review and approve new submitted artifacts when they conform to the representation.
12. *KM approaches should include verification methods*. The methods should verify knowledge artifacts for correctness, completeness, legitimacy, relevance, adequate specificity, and clarity. It is important that knowledge facilitators, not supervisors, review submitted artifacts. The review by the knowledge facilitators also provides them the opportunity to contact contributors for any clarifications that may be required, and to discuss any necessary corrections. This also allows the authors to be in agreement, and to have a chance to learn the best way to submit an artifact in the first place. KM approaches should also include maintenance methods so that stored knowledge remains relevant across time. For example, clustering methods can automatically identify redundant knowledge. Records of usage of artifacts can also indicate obsolesce. A committee of members must agree with deletions of artifacts. Automated methods of verification, maintenance and deletion can be adopted as long as they do not violate Guideline number 8.
13. *KM approaches should include measures to promote collaboration*. Collaboration is intrinsic to knowledge sharing because it is how groups of humans share and learn knowledge. Therefore, understanding the mechanisms that promote collaboration and computer-supported collaboration, and incorporating them into a KM approach, will increase its chances of promoting knowledge sharing. The essential element to foster collaboration is transparency (Stahl, 2005).

We recommend adopting a short and easily interpretable representation for knowledge artifacts to facilitate transparency. The easier an artifact is to understand more transparent are its contributor's interests. Consequently, collaboration is more likely to be promoted.

14. *KM approaches should demonstrate how contributors can benefit from KM*. Once contributors understand how they will benefit, they are more likely to be motivated to contribute (Atwood, 2002). They should also understand the value of the approach to others. Knowledge facilitators should emphasize the benefits of the approach to the contributors and to their community via tutorials and workshops. One motivating argument is to offer a benefit that compensates for the time spent on contributing to the KM approach. For example, contents of knowledge artifacts and community processes indicating where artifacts have been submitted can be used to help draft reports and illustrate contributor's performance. Knowledge facilitators should also educate and train users in order to minimize the time dedicated to submit artifacts. Moreover, contributors will more easily perceive benefits when using a well maintained repository with high quality artifacts.
15. *KM approaches should allow for the measurement of their effectiveness* (Ahn and Chang, 2002). The effectiveness of a KM approach should reflect its ability to perform knowledge tasks such as sharing and leveraging knowledge. For example, requesting that users search for associations between different repository artifacts requires their understanding of those artifacts. Thus, it points to knowledge sharing. Analogously, showing that a member has created a knowledge artifact with the use of an existing one would be a way to presume knowledge leveraging. Surveys asking users about their usage is also a way to measure effectiveness.

4. Implementing the knowledge management approach

The fifteen guidelines presented in the previous section constitute a conceptual model for a KM approach. The diverse sources of those guidelines, originating from the examination of factors that put KM approaches at risk of failure, provide support for an approach that has the potential to prevent failure. The organizational context where humans, processes, and technologies interact is much broader than the KM context alone. As we can see from the very definition of KM, it is constrained to the universe of knowledge assets, and so are its results and their impact. Nevertheless, as the guidelines of this model suggest, risk of failure may simply originate from the target community and not necessarily from the KM approach. Therefore, the conceptual approach we introduce and recommend in this work incorporates recommendations that sometimes go beyond the constrained universe of knowledge assets.

In this section we describe the conceptual KM approach in the context of an implementation that follows and meets the fifteen guidelines and constraints above. The implementation proposes ways of carrying out the approach and following the guidelines. They are not unique, and should be adapted to each specific context where the approach is implemented. The nature of the community is crucial in the choice of decisions on how to follow the proposed guidelines.

4.1 CAMRA community

The first guideline is a restriction imposed on the target community, that its members share similar goals in delivering the processes they want to impact. Our example target community is the Center for Advancing Microbial Risk Assessment (CAMRA) is a community established through joint funding from the U. S. Environmental Protection Agency and the U. S. Department of Homeland Security. CAMRA's mission is to advance the science related to threats originating from microbial agents of concern.

CAMRA can be considered a community because of its members. They are research scientists and their students. All members have similar stakes in the success of the center. Research scientists are being funded, and their success with respect to the goals of the center is decisive to their permanence as collaborators as their funding is conditional to it. Although some of the scientists also serve as directors, they are all in similar situations. The students in the project have their degrees associated to the goals of the center. Therefore, all CAMRA members share the same interests in advancing science and the success of the center, representing a *community of science*. This is a community that has innovation as its main goal. Peer criticism is considered one of their instruments of growth. All members are knowledgeable of the field, and able to absorb and retain new knowledge. Given that directors, research scientists, and students are all subject to goals defined in the original proposal, CAMRA is also an example of a flat hierarchical community.

CAMRA members include researchers who specialize in four aspects of microbial agents. Project I focuses on detection, fate and transport of agents; Project II on transmission and infection; Project III on dose response of contagious diseases in populations; and Project IV links technical research with study of public perception and compliance to governmental actions. A fifth project is dedicated to KM, which reveals the strong leadership support given to KM in this community.

Although seemingly representing different sub-areas, these projects share scientific activities such as the design and testing of models to represent behaviors in microbial risk assessment. Therefore, we can envision the center as being one community that focuses on a variety of contexts.

Our approach extends the concept of a community of practice to a community of science. Rather than a community that shares work practices (Davenport and Prusak, 1998), we focus on a community that shares scientific goals within a field of study. Although its stakeholders can be members of organizational institutions such as government, and even the public in general, the contributors to the system are experts in a field of study.

A community of science can meet many of the desired characteristics in a community for a successful KM approach. They encourage innovation, positive criticism, its leaders are likely to be role models in knowledge sharing, all members share the same goals, the hierarchy is flat, and all community members tend to be knowledgeable in the subject matter.

4.2 Integrating humans, processes and technology

The second guideline suggests that no single one of these individual components can be responsible for supporting a KM approach; a combination of these components is required. In this example implementation, the humans are knowledge facilitators, the processes are the ones delivered by the knowledge workers of the CAMRA community, and the technology is a knowledge-based KM system.

4.2.1 Knowledge facilitators

Knowledge facilitators are members of the KM team. They are an important component of the KM approach that we describe in this article. They are experts in KM issues and in repository-oriented KM systems. They are responsible for educating and motivating users to contribute and benefit from the approach. Knowledge facilitators keep open contact with all members, visiting them in person and holding workshops and tutorial sessions.
The relationship with stakeholders started at the time of conception of the approach, and moved into the design stage, when users communicate the useful processes of the community. Knowledge facilitators are mainly responsible for complementing the tasks of the KM approach that are not delivered by the technological component.

4.2.2 CAMRA processes

A community's processes refer to the tasks that members deliver, which are the ones that are supposed to be impacted by knowledge in the domain of the target community. Processes in any domain may be described in terms of activities that are somehow manipulated by knowledge workers who execute and improve knowledge in a domain. Activities in a domain are usually classified by members of this domain who recognize distinct categories. These categories can be described and visualized as taxonomies or networks. CAMRA's processes are the research activities in the domain of microbial risk assessment in Figure 1. This taxonomy is based on elements elicited during design and also from the ILSI Framework (ILSI, 1996).

During the submission of a knowledge artifact, contributors are presented with the list of processes so they can recognize the process they are working to improve. As contributors indicate the processes they are working on, they are asked to associate their artifacts to existing artifacts. This produces yet another map of their work, which will ultimately confirm or revise the organization of the domain taxonomies.

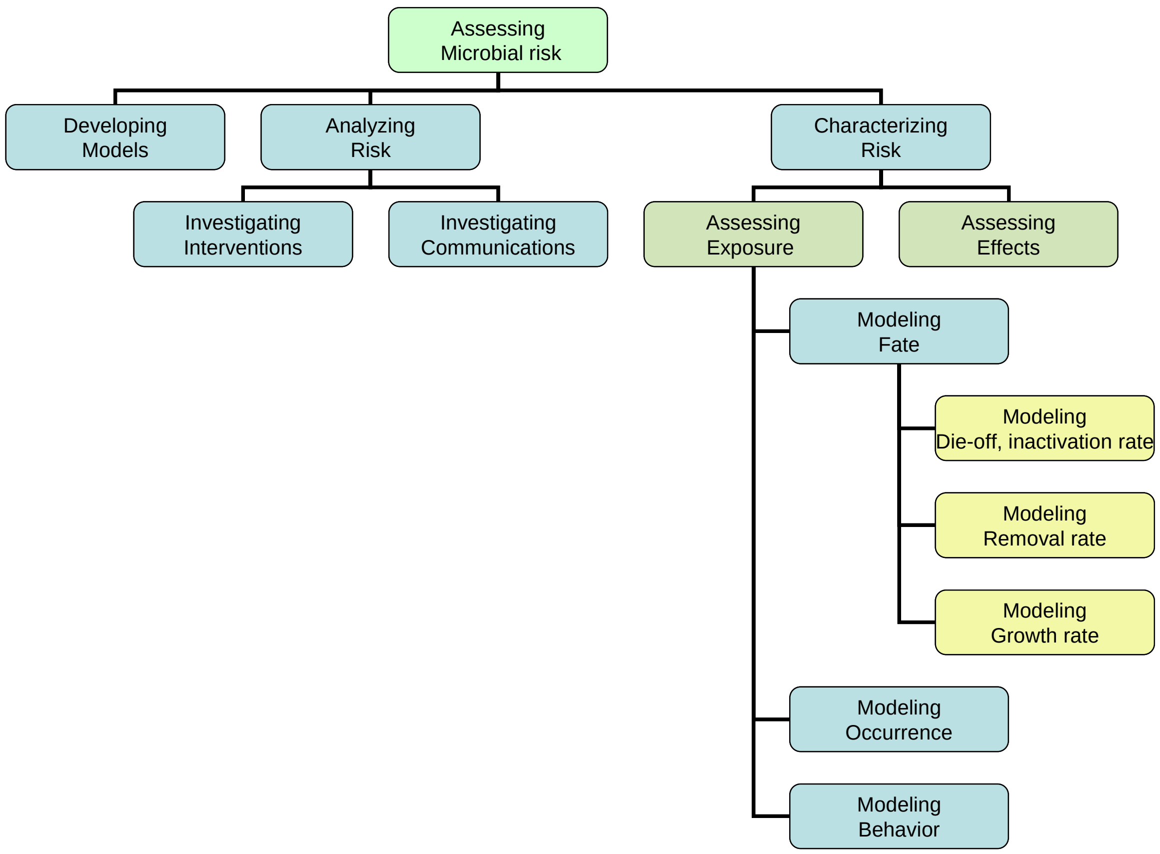

Figure 1. Partial taxonomy of research activities for CAMRA

4.2.3 Knowledge-based knowledge management system

The Knowledge-Based Knowledge Management System is the technological component of the approach. For CAMRA, it is a repository-based system that relies on the CBR methodology to represent, and potentially to reason with, knowledge artifacts. The artifact retained in the repository is a *learning unit (LU)*.

An LUs' representation is based on the concept of lessons-learned, which highlights four main fields (Weber and Aha, 2003), which were adapted to fit CAMRA's domain as Research Activity, Contexts, Contribution, and Support. These main fields represent the important aspects that are required in all LUs. No LU is approved unless it includes these four main fields.

Research Activity is the task or process where the LU is applicable, e.g., Assessing Exposure, Modeling Fate. *Contexts* provide additional circumstances that motivate applicability, e.g., pathogen is B. Anthracis, hosts are humans, environment is outdoor air. *Support* covers the unprovenness impediment by providing scientific evidence for the *Contribution*, which explicitly states a new scientific truth.

These four fields are based on case representation, so all methods designed for CBR are useful. Once the repository is populated, automated methods such as those for maintenance can be used. They will allow, for example, identifying a gap in the knowledge base, even suggesting which project should contribute filling this gap.

4.3 Stakeholder participation

The way we guarantee participation of multiple stakeholders in the design, is by adopting a cyclic design method. We invite participation from different stakeholders and go on with the design until we have working prototypes to be used. Then we obtain feedback. Details of this method are given in Weber et al. (2006).

4.4 Specificity of knowledge artefacts

The issue of specificity came up very early in the design meetings with the CAMRA community. Contributors felt unsure of which level of granularity they should adopt to contribute knowledge. The cyclic design is useful because it allows the group to revise the specificity initially adopted. For CAMRA, knowledge facilitators oriented the contributors to adopt a level that they would like to see in other contributor's artifacts. These decisions were crucial in defining the research activities as well.

4.5 Leadership support

The support of CAMRA leaders was obtained as knowledge facilitators explained the importance of their support and the benefits the approach could provide to the center. Benefits to the center include the ability to demonstrate how community members are working in integration, making the whole center more than the sum of its parts. Integration can be demonstrated by showing a map of the submitted LUs, along with how contributors associated new units with existing units (Figure 2).

CAMRA leaders are committed to the success of the KM approach. Thus, in terms of leadership support, the approach is not at risk of failure.

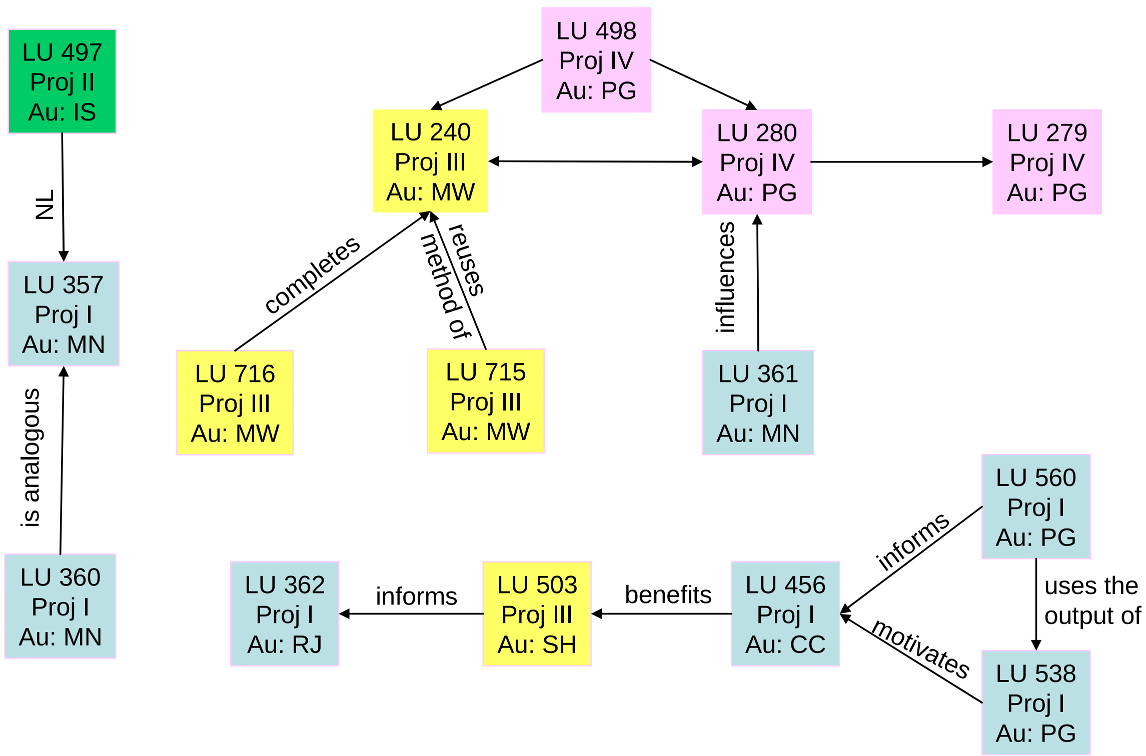

Figure 2. Map of LUs and their associations after the first few months of system in place

4.6 Encouraging innovation

Innovation is another restriction that does not pose a risk to implementing the approach to the CAMRA community. CAMRA is a community of science and it welcomes and rewards innovation and sharing it.
Representation
The adoption of LUs to represent knowledge artifacts is a way to meet the guideline that recommends using a set of fields to describe knowledge artifacts. The way we implemented it for CAMRA, we also limited the size of each field; this prevents long texts from being entered to describe knowledge artifacts. A reviewing process is also established where knowledge facilitators approve units for proper formatting. Knowledge facilitators explain to contributors that the contents of the LUs should simply describe the contribution, its support, the task it applies, and contexts. These are assumed to be the minimum elements for users to

understand the artifact. This promotes the easy interpretation of its contents. As users become interested in learning more about it, they can download attachments, read publications, and contact units' authors.

4.7 Reliable technologies

We meet the guideline of selecting adequate technologies as we adopt the CBR methodology to represent knowledge artifacts. We chose not to use automated methodologies for reviewing units because, when comparing natural language methods with humans for CAMRA, we find that the number of LUs still allows for revision by humans. There is no justification for the use of deep natural language methods that can be complex and expensive to implement.

4.8 Integration to community processes

Community processes are integrated into the approach as we request LUs to include the research activity that the artifact targets to contribute. The recommendation in Weber and Aha (2003) is to allow artifacts to be shared in the same context where activities are delivered. However, research activities are not like organizational tasks in businesses where tasks may be delivered in the context of a computational system. Therefore, we implement a dissemination method for CAMRA that is not proactive, but still follows the case-based retrieval in the monitored distribution (Weber and Aha, 2003). We adopt two pull and two push (Weber and Aha, 2003) dissemination methods.

Pull dissemination is available to all users in browsing and search. Browsing is the traditional database attribute-value selection where a user can view LUs that meet some criteria. Search is available from an interface that shows the same field structure as a learning unit. This way, users can select the specific process they are interested in to guide retrieval of LUs. This guarantees strong integration to community processes.

Learning units are pushed to users in active casting triggered in two ways. One is a decision that each user makes; when filling out their profile. Here, they can select research activities and contexts, and when a part of a submitted LU matches this selection, these units will be pushed to them. The other form is a decision of the contributors of each new unit. They are asked to list names of colleagues they would like the unit to be sent.

4.9 Enabling knowledge transfer

We enable knowledge transfer for the CAMRA community by providing a repository of knowledge artifacts using a methodology that allows for the identification of gaps. This is meant to prevent the need to explicitly specify how a contribution performs the research activity. Unprovenness is overcome by having knowledge artifacts include the scientific support for their stated contribution.

CAMRA members do not pose any risk with respect to their absorptive and retentive capacities. All members of this community are research scientists or are being trained to be.

4.10 Managerial responsibilities

We enforce those responsibilities by combining knowledge facilitators, community processes, and the KM system. The fields to be filled out when submitting a learning unit determine the knowledge that is to be shared. Those fields constrain contributors, so these constraints guide them on what it is to be shared. The system enables knowledge collection, as it is made available to all members of the community for contributing knowledge artifacts. Because the restrictions on the interface where units are entered, such as a drop down list of verbs for research activities, the system produces a representation for knowledge artifacts from their collection. The interface embeds the artifacts in targeted processes when it requires the selection of a research activity and contexts. The system does not accept the submission of units unless the main fields are filled. A reviewing process is established after a learning unit is submitted. Knowledge facilitators review units for appropriateness to the guidelines, while leaders of the center are informed of the submission of new units, so that they may contact the contributors if they have any suggestions. When the contributor is a student, a previously defined advisor is also notified, allowing them to discuss and revise the unit. The way we oversee knowledge reuse is by keeping track of the associations contributors indicate between a new unit and existing units. When contributors describe associations with terms such as influences, completes, or reuses, then they are explicitly communicating knowledge reuse. All the elements of the approach represent the infrastructure for the managerial responsibilities.

4.11 Verification

The reviewing process described in the previous sub-section is a way to verify knowledge artifacts for correctness, completeness, legitimacy, relevance, adequate specificity, and clarity. However, the approach specifies quality in a separate guideline because quality of knowledge artifacts is also a motivator for more contributions. It is a way to maintain the perception that the approach is valuable. This is another opportunity to rely on the CBR methodology for using automated methods to guarantee alignment to the approach. Maintenance methods can be used to identify obsolete and redundant units that may require removal.

4.12 Collaboration

The four main fields describing learning units highlight the main aspects needed for sharing. They are an attempt to make knowledge transparent, thus promoting collaboration. The assumption is that geographically dispersed researchers will feel comfortable contacting another member when they have this explicit representation of what the other member is doing. We hypothesize that this will promote collaboration.

4.13 Demonstrating benefits of the KM approach

This guideline aims at demonstrating the value of the KM approach to motivate contributions. We are concerned with the fact that although leadership recognizes value in KM, individual users may not. The result is that users may see contributing as an effort that is not properly compensated. Therefore, in addition to keeping artifacts of high quality, so users can perceive value in knowledge sharing, the guidelines propose that contributors receive something of value in return for submitting knowledge artifacts. For CAMRA, given that research scientists have to submit annual reports describing their research contributions, we implement this guideline by having the system automate the drafting of reports, so contributors do not have to do it. An introduction to this specific method is given in Weber, Gunawardena, and Proctor (2007).

4.14 Effectiveness

For CAMRA, the goals of implementing a KM approach are to promote knowledge sharing, leveraging, and integration among its members. Therefore, to meet the last guideline, we request that contributors associate knowledge artifacts. Before a new LU is submitted, there is a request to associate the new unit with existing units. The interface gives access to existing learning units and asks for a description of the association. Figure 3 is a snapshot of the first version of the system where descriptions of associations are free texts. Based on the design method we adopted (Weber et al. 2006), the descriptions captured in the first year of implementation are used in the second version and are presented as drop downs to facilitate guidance to contributors.

The important aspect of this description is how knowledge facilitators orient contributors on finding associations. They ask the contributors to identify associations that they believe are not obvious to laypersons, associations that a keyword method might not catch, associations they can recognize due to their expertise. The result is that we assume that once contributors find an existing unit that they can associate with their new one, that they have absorbed the contents of the existing unit, and given their expertise, they are likely to be able to retain it. Because this situation overcomes impediments to knowledge sharing, we find it reasonable to assume that knowledge was shared. Therefore, depending on the label selected by the contributor who finds the association, we can find evidence of knowledge sharing and leveraging. Figure 2 shows two linked units on the lower right corner, units 560 and 538 where the association is labeled as “uses the input of”. This is an instance that knowledge produced in LU # 538 was used as input to the knowledge built in LU # 560, suggesting leveraging. Notwithstanding, it is important to observe that we do not intend to claim that our KM approach is responsible for motivating those circumstances where knowledge was shared or leveraged. It is likely that these community members became aware of their colleague’s work through any other of the multiple effort the community makes to promote sharing and integration. The value of the KM approach is to be able to demonstrate that knowledge was shared. We also consider the step of associating units, an effort towards motivating integration. In the process of searching for existing units, the contributor has the chance to learn about other members’ activities and this allows them to recognize affinities. The associations all convey an idea of the whole, of which the contributor is a part.

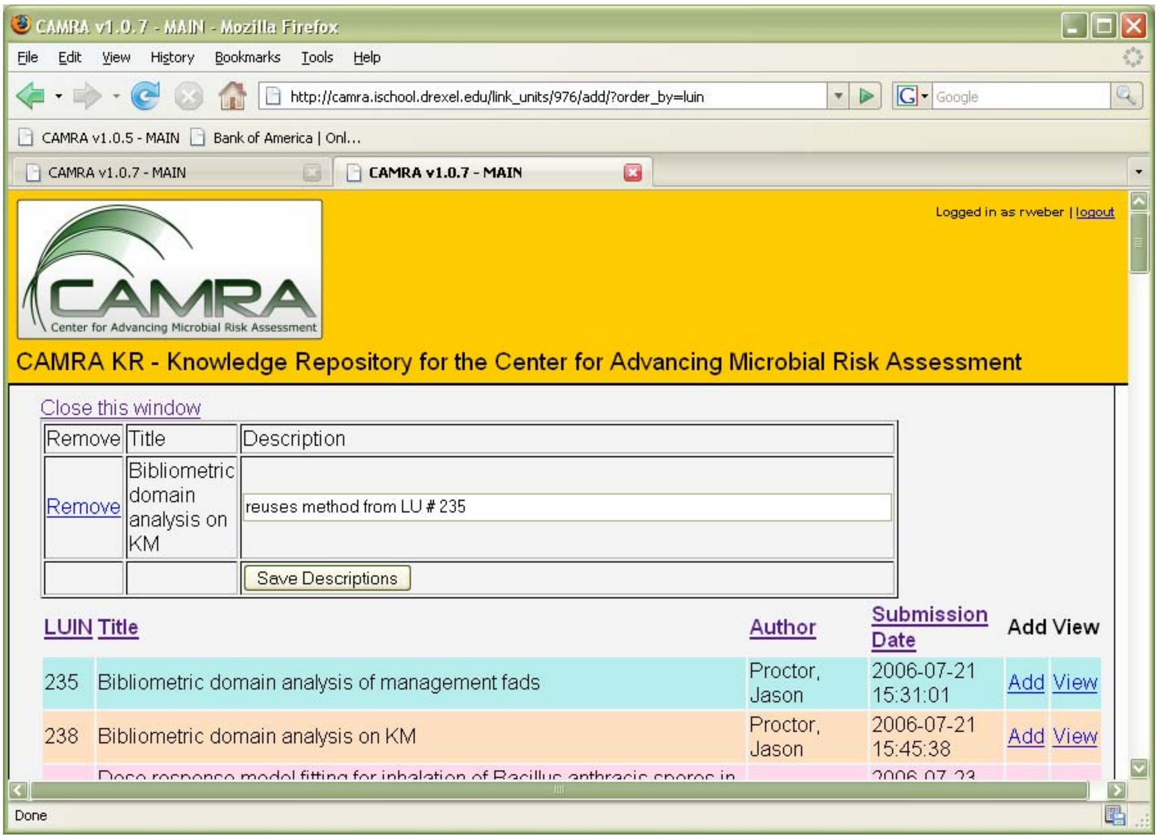

Figure 3. Associations between units are described by contributors.

5. Concluding remarks

In this article, we combined existing literature pointing to factors contributing to the failure of KM approaches into an approach for KM that is armed against the risk of failure originating in those factors. We listed fifteen guidelines describing this approach and illustrated their implementation with a deployed example.

Some of these guidelines impose a constraint rather than necessarily recommending a strategy. Consequently, one could conclude that communities where all members have the same technical goals, are motivated by a common interest, are organized on a flat hierarchy, and are receptive to innovation will be at less risk of failure when implementing a KM approach.

Although these guidelines are geared towards preventing those failure factors, it is possible that some of the strategies are not sufficiently effective. Multiple implementations of this approach in different target communities are necessary before we can determine its level of effectiveness.

There are still some points in the approach to be explored. For example, implementing automated maintenance methods to help identify gaps in the knowledge base, and indicating potential research questions for the community.

The aspect of utilizing the representation of knowledge artifacts to provide transparency and promote collaboration deserves further study. The assumptions we use are reasonable but the result anecdotal.

In reference to the example implementation in CAMRA, knowledge facilitators visited all the institutions to meet with community members. They all submitted units and had the opportunity to learn from other contributors. The presence of a knowledge facilitator to motivate them to use the system and to enhance the system's capabilities has shown to be crucial to the acceptance of the system from its users.

The next main step is the release of the newest version that includes automated reports. We expect that this will become the main motivator for the use of the system, making the presence of a knowledge facilitator less important.

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