INSTITUT NATIONAL POLYTECHNIQUE DE GRENOBLE

T H E S E

pour obtenir le grade de

DOCTEUR DE L'INPG

Spécialité : «Génie Industriel»

préparée au laboratoire GILCO (Gestion Industrielle Logistique et Conception)
dans le cadre de **l'Ecole Doctorale «Organisation Industrielle et Systèmes de Production»**

présentée et soutenue publiquement

par

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le 26/08/2005

From Quality Management to Knowledge Management in Research Projects: An Approach through the Management of Contents in Bibliographical Research

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Acknowledgements

Many people and institutions made this thesis possible. The support I have received during the last three years this research project has demanded appears at many different levels: Scientific, organizational, financial and even emotional. All these contributions have allowed me to achieve this work and for that reason, I am deeply grateful.

First of all, I would like to express my gratitude to the members of the dissertation committee for having accepted to evaluate this research work:

- I would like to express my sincere thanks to Prof. Dr. Jean-Claude BOCQUET, research director at the Industrial Engineering Laboratory of the Ecole Centrale Paris, in France, for having accepted to preside over the dissertation committee.

- I would like to express my gratitude to Prof. Dr. Michel ALDANONDO, of the Industrial Engineering Centre at the Ecole de Mines d'Albi Carmaux (School of Mines of Albi Carmaux), in France, for having accepted to review this work and being part of the dissertation committee.

- I would like to express my special thanks to Prof. Dr. Manuel Zacklad, of the ISTIT Laboratory (*Institut des Sciences et Technologies de l'Information de Troyes*- Institute of Sciences and Information Technologies of Troyes), Tech-CICO Team (*Technologie de la Coopération pour l'Innovation et le Changement Organisationnel* - Co-operation Technology for Innovation and Organisational Change), at the Technology University of Troyes, in France, for having accepted to review this work and being part of the dissertation committee.

- I would like to express my deep thanks to Prof. Dr. Graham BUTTON, of the Sheffield Hallam University, in the United Kingdom, for having accepted to examine this work and being part of my dissertation committee.

I would like to express my very special gratitude to Dr. Mickaël GARDONI, Assistant Professor at the National Polytechnic Institute of Grenoble (*Institut National Polytechnique de Grenoble - INPG*) and member of the GILCO laboratory for having accepted to be my advisor and director. I am deeply grateful for his strong support and advice during these years. He was always very open to new ideas and encouraging during all my research work. His capacity for diligently managing this PhD project was fundamental for keeping the work on track and achieving this dissertation. Also, the time he dedicated to my work together with his continual challenging questioning allowed me to deep into the subjects treated. I would also like to thank him for his strong support during the development of the BASIC Lab prototype. His insights and supervision of the graduate students who developed it, as well as the supervision of the engineering student who performed the second phase of its trials, were deeply appreciated.

A special thank also to Prof. Dr. Dominique Vinck, professor at the Pierre Mendès-France University and at the National Polytechnic Institute (INPG) of Grenoble and director of the Research Centre on Socio-technical Innovation and Industrial Organisation of the Pierre Mendès-France University. His contribution to the methodological design of this work constitutes one of the essential factors of this dissertation. His challenging questioning allowed me to enrich the analyses made and explore further possibilities and was decisive for the improvement of the conceptual framework of the work.

I would also like to thank Mr. Joël MOSCA, associated professor at the National Polytechnic Institute of Grenoble (INPG). His hands-on experience in the field of quality management was crucial for getting closer to reality. His continual support, interest and feedback towards my work were always very encouraging. His support during the field work was fundamental for gaining a deep understanding of the studied processes.

I would like to thank Prof. Dr. Yannick FREIN, Professor at the National Polytechnic Institute of Grenoble (INPG) and director of the GILCO laboratory, for having accepted me in his team and for supporting my research project.

I would like to express my very special thanks to the personnel of the laboratories that allowed me to make the field work. The ACROE – ICA, the LAOG, the CERMAV, the LIS, the LCMI, the LECA, the SERAS, and the 3S, were all very kind and responded to my questions, particularly regarding their experience with quality management. Several people in these organizations should be thanked for granting me part of their valuable time to answer my questions. The list would be long and probably incomplete. For that reason, I would only mention a few people whose support was fundamental. Special thanks to Annie LUCIANI, Claude CADOZ and Jean-Loup FLORENS, of the ACROE – ICA, who allowed me to observe the research activity at the laboratory and were always opened to my questions. My sincere gratitude goes also to Dr. Didier FRAIX-BURNET, of the LAOG, and to Eng. Alain RIVET, of the CERMAV, who allowed me to follow the implementation of the quality management system at their laboratories. They were always very open, allowing me to observe different aspects of the implementation, such as the activities undertaken and the problems faced, which was fundamental for the subject treated. In addition, Eng. François DEBRAY, of the LCMI, Prof. Dr. Jacques DESRUES, of the 3S laboratory, Dr. Pierre TABERLET, of the LECA, M. Jean-Paul ROUX and M. Philippe JEANTET, of the SERAS and Mme. Jeanne MALBOS, of the LIS, should also be thanked for taking the time to answer my questions about the experience of their organizations in the implementation of quality management systems.

Furthermore, I would like to thank all my colleagues at the GILCO laboratory, for their support, their patience with my questions, their cooperation with the trials of the BASIC Lab prototype and the stimulating working atmosphere they provided.

I would like to specially thank Faouzi AMIER and Djaouad Mohamed AROUA, whose dedication and professionalism made the development of the BASIC Lab prototype possible. Also, my gratitude to Helder VASCONCELOS, whose collaboration with the trials of the prototype was highly valuable.

Many other people were involved in the realization of this project. I would like to express my gratitude to all these people for their support. I can only mention some of them, and ask the others their comprehension and acceptance of my apologies. To my friend Martha HUERTAS, whose patience dedication with the revision of the English grammar of many of the publications that resulted from this work, was much appreciated. My deepest gratitude to my friend Olga COLLAZOS, and to her husband Andrew, who patiently reviewed the English grammar of this dissertation, making it clearer than it originally was.

In addition, at a more personal level, many people provided a valuable support that also contributed to the achievement of this dissertation. To them, my deep thanks. They supported me and encouraged me to continue, even from the distance. To my friend Angela CARRILLO, whose encouragement and friendship were always present. To my friend Mario ROMERO, for the great support during all the years this work lasted. The numerous ways in which he helped me could not be fairly listed. His patience, understanding, collaboration and kind friendship provided a pleasant environment to go on and were crucial for the achievement of this work.

My parents, German and Aide, my sisters, Gloria and Yamile, as well as the other members of my family, receive my deepest gratitude for the many years of support and especially for always believing in me.

September 2005, Grenoble

Contents

List of Annexes

List of Figures

List of Tables

“If I have seen further, it is by standing on the shoulders of giants.” Isaac Newton

Résumé en français

De la gestion de la qualité à la gestion des connaissances dans les projets de recherche : Une approche par la gestion du contenu pour la recherche bibliographique

Introduction

L'activité de recherche implique la manipulation d'informations et de connaissances. A partir de ces ressources, de nouvelles connaissances sont produites, pour devenir, elles-mêmes, les ressources de nouvelles recherches. En fait, selon (Chalmers, A., 1991), « le but de la science est de produire de la connaissance sur le monde ». C'est pourquoi; nous nous sommes intéressés aux pratiques formelles de gestion des connaissances (KM) introduites par les organismes de recherche (OR) lors de la mise en place d'une démarche qualité.

En France, des réflexions sur la possibilité d'appliquer des concepts et méthodologies de la qualité au processus de recherche ont été menées et un document intitulé «Guide expérimental pour la qualité en recherche» a été rédigé par le (Groupe de Travail Français «Qualité en Recherche», 1997). Ce document a été repris par l'(AFNOR, 2001) comme base du Fascicule de Documentation FD X 50 – 550 «Démarche qualité en recherche – Principes généraux et recommandations», dans lequel la démarche qualité est proposée comme une possibilité pour faire face aux multiples enjeux des activités de recherche.

De plus, dans les dernières années, quelques organismes de recherche se sont intéressés à la démarche qualité comme moyen pour améliorer leurs activités. Cependant, elles présentent des spécificités en termes de buts, ressources, pratiques et organisation qui rendent ces activités très différentes des activités industrielles, où la démarche qualité a été traditionnellement appliquée. Ainsi, l'introduction de la démarche qualité appliquée à l'industrie n'est pas transférable point à point dans l'environnement scientifique.

L'AFNOR préconise l'utilisation de la démarche qualité par les acteurs scientifiques. De fait, des organismes de recherche mettent en place une démarche qualité au sein de leur organisation. Aussi, nous nous sommes engagés dans un processus de recherche qui vise à étudier le rôle que cette démarche qualité peut jouer dans la transmission des connaissances. Notre objectif est notamment de vérifier l'hypothèse selon laquelle la démarche qualité peut être utilisée pour supporter le processus de production de connaissances à travers l'utilisation de méthodes issus du domaine du KM.

À cette fin, nous avons étudié quelques OR qui ont établi des projets visant l'amélioration de leurs activités à travers la mise en place d'une démarche qualité. Notre première hypothèse était que l'axe central de la démarche qualité serait les activités de recherche et que ceci exigerait l'introduction des pratiques formelles de KM. Nous avons commencé notre recherche par des travaux de terrain. Cette phase nous a permis de connaître les pratiques formelles de KM introduites par ces OR lors de la mise en place de la démarche qualité. L'information recueillie a été employée pour définir une approche visant l'application du KM dans ce type d'organisme.

Dans la première partie, nous avons souhaité décrire le fonctionnement réel de quelques unités de recherche qui mettent en place une démarche qualité. Dans la deuxième partie, nous décrivons les pratiques de KM observées dans quelques unités de recherche. Dans la troisième partie, nous proposons une approche pour introduire le KM dans ce type d'organisme. Puis, nous présenterons la conception d'un outil pour supporter l'approche que nous proposons. Dans la dernière partie, nous présentons le prototype de l'outil en question.

La Démarche Qualité dans le Contexte de la Recherche

L'implémentation de la démarche qualité dans les organismes de recherche répond à une série d'enjeux scientifiques, économiques et financiers, sociétaux et environnementaux, pour ces organismes de recherche et pour les chercheurs (AFNOR, 2001). Néanmoins, la mise en place d'une démarche qualité dans un organisme de recherche n'est pas chose aisée. Il s'agit, tout d'abord, de se faire une idée précise de cette activité spécifique, afin d'imaginer des méthodes et des outils appropriés. Les activités de recherche produisant essentiellement de la connaissance, sa capitalisation, usuellement sous la forme de documents qu'il faut gérer, est une préoccupation présente dans le milieu de la recherche. Notre attention porte particulièrement sur cette dimension de l'activité de recherche.

Dans ce cadre, nous avons étudié la façon dont plusieurs entités de recherche mettent en place la démarche qualité, en portant une attention particulière à la gestion de l'information (donnés, documents, etc.). L'hypothèse est que ces supports d'information concrétisent en partie les connaissances développées au sein de l'entité de recherche. Notre approche est d'étudier le processus suivi dans l'activité de recherche. Nous nous appuyons sur un travail de terrain qui nous a permis d'acquérir de la connaissance sur la réalité en question. Ce travail a été réalisé en plusieurs phases :

- La collecte d'informations (observation directe et entretiens) sur le fonctionnement courant d'un laboratoire de recherche, pendant quatre mois,
- La réalisation de huit entretiens avec les personnes responsables de la démarche qualité dans sept laboratoires de recherche où des efforts formels d'introduction de cette méthodologie sont en cours,
- Le suivi du processus d'implantation de la démarche dans un laboratoire de recherche. Ce travail est mené via la participation aux réunions de travail.

Par la suite, nous présenterons les principaux résultats de ce travail de terrain.

● La Réalité Observée dans un Laboratoire de Recherche

L'observation du terrain a permis de constater que plusieurs caractéristiques de l'activité de recherche rendent difficile sa gestion : la diversité de champs d'activité au sein d'un même laboratoire, la grande quantité d'enregistrements (rapports et fichiers numériques notamment) à gérer, la multiplicité des méthodes de travail, la grande rotation du personnel, la multiplicité d'activités qui doivent être développées en parallèle, avec des horizons de travail divers, et qui doivent être coordonnées pour aboutir à des résultats valables, la nécessité, et en même temps la difficulté, de définir clairement l'objectif à atteindre, la difficulté pour établir dès le commencement d'un projet les caractéristiques précises du produit de la recherche (qu'il s'agisse d'un produit physique ou d'un produit conceptuel), l'intérêt d'avoir des dispositifs de suivi et d'accompagnement pendant le processus de recherche, la difficulté pour accéder à l'histoire d'un projet et l'importance de la mise en place de procédures de validation des résultats, etc. Toutes ces caractéristiques compliquent l'optimisation de la gestion des connaissances et la définition d'une instrumentation standardisée.

Une des particularités de l’activité de recherche étant d’accroître les connaissances et d’entrer dans une démarche cumulative, la question se pose de savoir comment capitaliser ces savoirs et comment rationaliser et instrumenter l’activité. Or, dans l’organisme observé, nous avons remarqué que des pratiques de travail et de gestion affectent les résultats obtenus, par exemple la liberté laissée aux chercheurs pour l’enregistrement ou la traçabilité de leur production. À part les rapports de recherche, mémoires et publications, les autres types de traces sont très peu formalisées. Même si leurs contenants sont parfois formalisés, voire standardisés, les contenus enregistrés dans les documents de travail sont très disparates. Les connaissances étant en partie concrétisées dans ces contenus, leur partage en est affecté et par voie de conséquences, ne sont pas suffisamment capitalisées pour le bénéfice futur de l’activité de recherche.

- Quelques Expériences de Mise en Place de la Démarche Qualité

Nous avons également effectué huit entrevues dans sept entités de recherche, relevant du CNRS, déjà engagés dans la démarche qualité. Ce sont tous des laboratoires de recherche, excepté un service qui fonctionne pour les laboratoires de recherche comme fournisseur d’équipements spéciaux requis dans des projets de recherche. La plupart des autres organismes combinent des activités de recherche appliquée et de recherche fondamentale. Or, nous constatons que la gestion de la qualité est essentiellement au niveau des activités administratives et/ou des activités techniques. Dans la plupart des cas, l'activité de la recherche fondamentale n’entre pas encore dans le système de qualité, parce qu'elle est perçue, en général, comme une activité de nature différente pour laquelle la mise en œuvre d’une démarche qualité est programmée pour une étape plus avancée.

Les démarches observées s’inspirent du standard ISO 9001 (AFNOR, 2000) et le résultat est souvent l'établissement de systèmes d'information, lesquels visent à faciliter la réalisation des processus répétitifs. La principale différence entre les systèmes qualité tient au type d'activité concerné : deux des organismes fonctionnent dans la recherche appliquée (où la démarche qualité est employée seulement pour cette activité) tandis que les autres travaillent principalement en recherche fondamentale. Cette différence occasionne des divergences dans la manière d'établir les démarches : les premiers, ceux qui font la recherche appliquée, ont suivi un processus classique pour l'établissement d'un système qualité selon le standard ISO 9001, alors que le deuxième groupe, qui travaille en recherche fondamentale, s'est beaucoup interrogé sur la façon dont la démarche qualité pourrait être appliquée à la recherche.

L'(AFNOR, 2001) propose, aux organismes de recherche voulant s'engager dans une démarche qualité, d'établir des dispositifs pour maintenir la qualité de l'activité de recherche pendant tout le processus de production scientifique jusqu'à la validation des résultats, en laissant la définition précise de ces dispositifs à chaque organisme de recherche. C'est pourquoi, nous avons étudié les différentes approches utilisées par des entités de recherche mettant en place la démarche qualité, en portant une attention particulière à la gestion de l'information, vu le support qu'elle offre à la capitalisation de connaissances. Nous allons maintenant présenter nos observations de la réalité de la recherche en ce qui concerne les pratiques formelles de gestion de connaissances introduites à travers la démarche qualité.

Pratiques Observées de KM

Suite à l'étude de terrain, nous avons observé que de nos jours, les projets de mise en place de la démarche qualité se focalisent principalement sur les activités administratives et/ou techniques et très peu sur les activités de recherche fondamentale. La méthode actuelle est essentiellement basée sur l'écriture de documents (des procédures opérationnelles et d'autres documents). Pour la gestion de ces documents, des systèmes d'information, souvent un Intranet qui contrôle parfois d'autres documents de l'organisation, ont été établis (Gandon, F., et al., 2002). Cependant, ces systèmes ne cherchent pas « la gestion et la circulation des connaissances distribuées » comme dans des projets tels que COMMA (Gandon, F., et al., 2002). Dans les OR que nous avons enquêté, les systèmes d'information permettent de trouver des documents ou de l'information (qui guide la réalisation des activités). En général, les documents produits pendant le processus de recherche ne sont pas maîtrisés par ces systèmes. En conséquence, nous n'avons pas pu vérifier notre hypothèse sur l'utilité du KM comme base pour l'amélioration des activités de recherche. Cependant, les organismes que nous observons continuent à travailler à l'amélioration de leurs activités et des aspects tels que la gestion électronique des documents, la gestion de projets et le KM commencent à apparaître. Pour cette raison, nous avons commencé à chercher des possibilités d'introduire des pratiques de KM dans le processus de recherche. C'est le sujet que nous présentons dans le chapitre suivant.

Une approche pour mettre en place le KM

Dans ce contexte, nous nous sommes intéressés à identifier des moyens pour gérer les connaissances produites lors de la réalisation des projets de recherche. Cependant, (Wunram, M., et al., 2002) indique que les approches « qui commencent avec le but de capturer toute la connaissance des employés sont prédéterminées à échouer ». Il est donc nécessaire de définir les connaissances qui peuvent être les plus favorables aux activités de recherche.

• Quelles Connaissances Gérer ?

Etant donné notre intention d'améliorer le processus de production des connaissances, nous avons effectué une analyse des activités réalisées au cours du développement des projets de recherche. Nous avons prêté une attention particulière à l'information employée et produite lors de ces projets. Nous en avons conclu que les connaissances produites pendant la réalisation des projets de recherche restent pour la plupart peu capitalisées (en général, seuls les résultats finaux sont capitalisés).

Dans ce contexte, le concept d'artefact nous semble utile. En effet, (Hutchins, E., 1999) indique que les artefacts sont des « dépôts des connaissances... construits dans des médias durables ». (Michaux, V., Rowe, F., 2003) ajoutent que « la cognition distribuée considère que les artefacts contiennent une partie de la connaissance nécessaire pour achever une action quotidienne avec efficacité… l'autre partie étant tenue d'une manière complémentaire par les hommes ». En conséquence, nous considérons qu'un artefact est un élément ayant une forme matérielle (ou une forme virtuelle, étant donné qu'elle peut exister uniquement dans un système informatique) qui véhicule une partie des connaissances détenues par son auteur, à condition que le récepteur connaisse le contexte dans lequel il a été créé et détienne la connaissance nécessaire pour son interprétation. En ce sens, les artefacts donnent une représentation qui peut être stockée et potentiellement, partagée et réutilisée. Citons trois exemples d'artefacts : Un cahier de laboratoire, un compte-rendu de réunion ou un article scientifique.

Dans le contexte de la recherche, les actions quotidiennes qui nous intéressent sont liées aux projets de recherche. Nous avons observé que dans la réalisation des projets de recherche il existe une grande quantité d'artéfacts produits. Étant donné que ceux-ci véhiculent la connaissance, nous nous concentrerons sur la capitalisation des artéfacts. La question est maintenant : comment capitaliser ces artéfacts comme moyens pour faciliter la réalisation les projets de recherche ? Afin de répondre à cette question, nous avons commencé par analyser les moyens par lesquels des artefacts sont produits pendant la réalisation d'un projet de recherche. Cette analyse est décrite dans la section suivante.

• Comment sont produits les artéfacts ?

En nous basant sur la littérature de la Sociologie des Sciences[1] et sur nos propres observations, nous proposons une représentation des projets de recherche. Pour cela, nous nous inspirons de la modélisation SADT (*Structured Analysis Design Technique* - technique de conception d'analyse structuré) (voir Figure 1). Nous avons ajouté quelques formalismes additionnels qui nous permettent de différencier : i) - les activités exécutées, les activités routinières, les activités semi routinières et les activités intellectuelles ; ii) - les résultats obtenus, les résultats principaux, les résultats secondaires et les résultats inutilisés (tels que des documents).

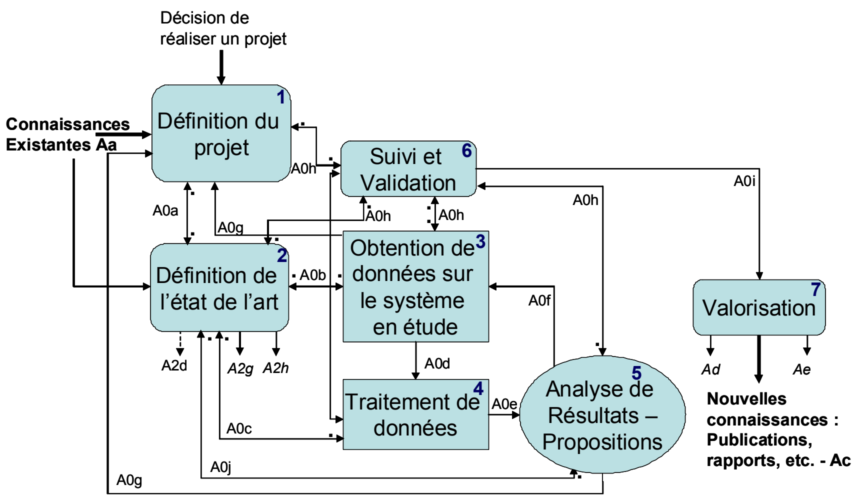

Figure 1. Représentation d'un projet de recherche.

[1] Principalement, textes tels que : (Vinck, D., 1995).

La figure 1, présentant un niveau du modèle SADT, montre deux aspects principaux :

- la non linéarité des projets de recherche, en effet, les chercheurs sont fréquemment obligés de revenir aux phases antérieures du projet.
- malgré le fait que les projets de recherche sont en général non routiniers, il existe des activités semi-routinières et routinières. Ceci est très positif pour nous, parce que nous pouvons espérer proposer des pratiques ou des outils offrant un certain support aux activités de recherche.

De plus, il existe deux aspects importants à noter au sujet de ce modèle :

- Ce modèle est intentionnellement général et non centré dans un domaine de recherche spécifique. D'ailleurs, étant intéressés par les artefacts produits, nous nous focalisons plus sur les *flèches* et moins sur les *boîtes* contenues dans le modèle, car les flèches représentent les artefacts produits et transitant pendant un projet de recherche.
- grâce au modèle, nous avons pu identifier 102 artefacts. Nous les avons classés en trois catégories : ceux liés à la bibliographie (publications, rapports de recherche, livres, notes des chercheurs, documents, concepts trouvés dans les documents, etc.), ceux liés à la gestion du projet (le plan de projet, les comptes-rendus, etc.) et ceux liés aux résultats intermédiaires (des logiciels et des instruments ayant étés développés pour un projet, des données recueillies et traitées, etc.).

Notre objectif est d'identifier des moyens pour capitaliser ces trois types d'artefacts. Ceci est le sujet de la section ci-après.

• Comment gérer les artefacts ?

Dans notre recherche des moyens pour capitaliser les artefacts, nous avons identifié principalement deux possibilités : Des outils méthodologiques et des outils informatiques. Concernant les outils méthodologiques, nous avons centré notre attention sur les méthodes de capitalisation telles que SPEC (Bekhti, S., Matta, N., 2003). Malgré l'existence de plusieurs méthodes pour la capitalisation de la mémoire de projet, celles-ci ne sont pas adaptées aux caractéristiques des projets de recherche, particulièrement en raison de l'environnement dynamique et de la non répétitivité des projets. C'est pourquoi, nous nous sommes intéressés aux possibilités offertes par les technologies de l'information pour capitaliser les artefacts comme moyen de faciliter la réalisation des projets de recherche.

- Les outils informatiques proposés pour la gestion des connaissances

Dans notre recherche des possibilités pour structurer des artefacts, nous avons commencé par étudié les outils de KM actuellement disponibles sur le marché. Baroni de Carvalho R et Araújo Tavares M. (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002) ont défini les logiciels de KM comme « un type de logiciel qui soutient n'importe lequel des trois processus de base de KM (Davenport et Prusak, 1998) : génération, codification et transfert ». Le résultat de ce travail est présenté dans (Jaime, A., et al., 2004). Ici, nous pouvons résumer la situation concernant des outils de KM comme suit :

- il existe un certain nombre d'outils intéressants offrant des fonctionnalités pour la gestion de projets,
- il existe quelques outils offrant des fonctionnalités pour la gestion des données, qui pourraient soutenir la gestion des données recueillies et traitées ;
- finalement, quelques outils gèrent des aspects particuliers de la gestion de la bibliographie : Gestion de Documents, gestion des références et visualisation des références

On voit donc une situation où les outils pourraient supporter la gestion des artéfacts liées à la gestion de projets et aux résultats intermédiaires (notamment les données), mais où le support pour les artéfacts bibliographiques est limité à quelques aspects précis, où le contenu de ces artéfacts n'est pas traité. Dans la prochaine section nous allons voir quelques outils développés par des chercheurs pour gérer les connaissances dans les organismes de recherche.

- Quelques logiciels de gestion des connaissances développés par et pour les organismes de recherche

Nous avons pu identifier certains des efforts effectués par des chercheurs pour la capitalisation de la connaissance dans des activités scientifiques.

Parmi ces travaux, nous trouvons [2]:

- Le Digital Document Discourse Environment (environnement de discours du document Digital) (Buckingham Shum, S., Motta, E., Domingue, J., 1999), qui facilite le processus d'évaluation par ses pairs en permettant d'ajouter des annotations aux documents scientifiques et les transformant en un "site Web structuré de discussion".
- ScholOnto (Buckingham Shum, S., Motta, E., Domingue, J., 1999) qui est une ontologie « conçu pour soutenir les chercheurs dans la réalisation des affirmations en présentant les rapports entre concepts ».
- ANITA (Gardoni, M., et al., 2004) qui est un outil qui permet d'annoter des documents ou des parties de documents.

Ces outils présentent quelques dispositifs très intéressants. Cependant, la plupart d'entre eux ne tiennent pas compte de la capitalisation des artefacts utilisés et produits pendant la réalisation d'une recherche bibliographique. Pour cette raison, nous avons décidé de travailler vers la définition d'un outil qui pourrait soutenir cette activité.

La Conception d'une approche pour gérer les connaissances lors de la recherche bibliographique

Etant donné l'absence d'outil permettant de gérer et de capitaliser les artefacts utilisés et produits pendant la réalisation de la recherche bibliographique, nous avons décidé de nous concentrer sur la définition d'une approche soutenant cet aspect. Il est important de clarifier, que ce que nous comprenons par recherche bibliographique est toute la relation qu'un chercheur, une équipe de projet et même un laboratoire dans son ensemble, ont avec des sources bibliographiques (tels que les bibliothèques, les bases des données, les périodiques et des personnes). C'est-à-dire : à partir de la recherche initiale de la connaissance disponible

[2] D'autres travaux intéressants sont : Epistheme (Oliveira, J., et al., 2003), le Software for Technology Intelligence System- STIS (logiciel pour le système d'intelligence de technologie) (López-Ortega, E., et al., 2004), la système de partage de connaissance qui est en train d'être développé chez Nectec (Vorakulpipat, C., 2004) et l'architecture proposée par Sarini et al. (Sarini, M., et al., 2004) pour appuyer le travail des biologistes à travers de l'utilisation d'un système basé sur les cahiers de laboratoire électroniques.

probablement utile pour traiter une question scientifique, jusqu'au moment où des nouveaux documents (notamment publications) sont produits. Dans ce chapitre nous présentons les analyses faites pour définir les spécifications de l'approche que nous proposons.

• L'analyse fonctionnelle

Afin de commencer notre recherche sur les possibilités de capitaliser les artefacts identifiés et produits pendant la réalisation d'une recherche bibliographique, nous avons réalisé une analyse fonctionnelle (voir figure 2).

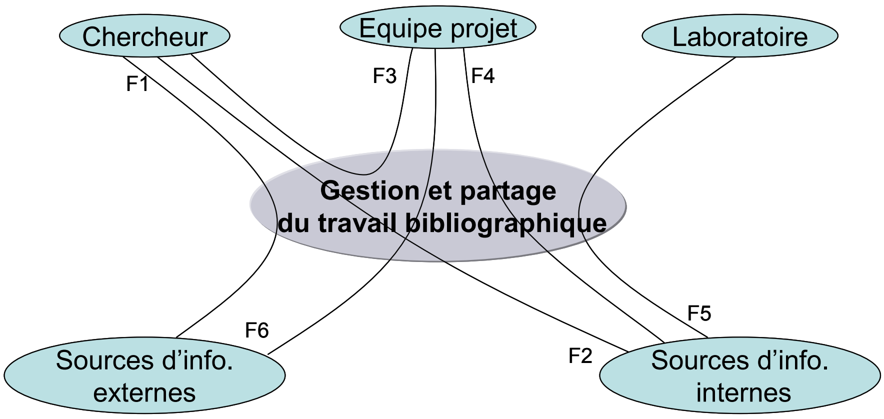

Figure 2. Analyse fonctionnelle d'un outil pour gérer et capitaliser le travail bibliographique.

Nous avons identifié trois acteurs : le chercheur travaillant individuellement, l'équipe projet, où les chercheurs interagissent et le laboratoire dans sa totalité, où les différentes équipes de projet interagissent et partagent les connaissance acquises.

Ces trois acteurs interagissent principalement avec deux entités pour effectuer le travail bibliographique : les sources d'information externes et internes; les deux sont régulièrement enrichies par le travail effectué par les équipes de projet pour permettre son partage. Cette interaction est effectuée à travers la réalisation des fonctions suivantes :

- F1 : Repérer et analyser l'information jugée intéressante dans les sources d'information externes,
- F2 : Choisir et analyser l'information jugée intéressante dans les sources d'information internes,
- F3 : Apporter de l'information pertinente dans un projet en cours,

- F4 : Permettre l'enrichissement des sources d'information internes,
- F5 : Partager l'information bibliographique recueillie et produite,
- F6 : Supporter l'écriture des publications.

Avec ces spécifications des fonctions, ci-dessus, auxquelles le système devrait répondre, nous avons vérifié si les outils de KM déjà identifiés (voir la section « Comment gérer les artefacts ? ») pourraient y répondre. Nous avons alors déterminé qu'il existe des outils qui soutiennent certaines de ces fonctions. Cependant, ils offrent seulement un appui partiel à toutes les interactions d'un chercheur avec les artefacts bibliographiques et ils ne les gèrent pas comme un support au développement des projets de recherche.

D'ailleurs, il existe une fonction très importante pour laquelle nous n'avons pas pu identifier d'outil. Il s'agit de la gestion des concepts scientifiques qui apparaissent dans les sources bibliographiques. Concrètement, nous n'avons pas pu identifier de solution abordant le travail effectué par des chercheurs lié à la localisation et à l'extraction des définitions et des descriptions des concepts contenus dans les documents résultant des processus de recherche. Nous considérons que cet aspect est très important pour l'activité de recherche. En fait, selon (Dunbar K., 2004) « plusieurs chercheurs ont noté qu'une composante importante de la science est la génération de nouveaux concepts et les modifications des concepts existants ». C'est pourquoi nous avons l'intention de supporter ce processus en soutenant le travail bibliographique.

Il est à noter que nous souhaitons notamment faciliter le processus qui permet aux chercheurs d'identifier la diversité des approches exposées dans la littérature scientifique pour un même concept. En fait, nous avons observé qu'une partie du travail qu'une équipe de projet de recherche devrait effectuer est précisément de répertorier cette diversité et de définir si une des approches identifiées peut être employée ou s'il est nécessaire de développer une nouvelle approche. Ce processus devrait permettre à l'équipe d'établir le cadre conceptuel du projet et qui servirait d'appui aux autres activités effectuées pendant la réalisation du projet. L'objectif serait ensuite de partager ce travail avec d'autres membres de l'organisation comme moyen pour établir une vue plus complète des domaines dans lesquels l'organisation développe sa recherche. Néanmoins, il est important de mentionner que nous souhaitons offrir aux chercheurs une manière de représenter la diversité des points de vue existants.

● La modélisation du système avec UML

Afin d'établir une proposition des spécifications fonctionnelles du système, nous l'avons modélisé en utilisant UML (Unified Modeling Language).

Nous avons commencé par identifier les utilisateurs :

- Chercheur Individuel : Qui localise les contenus englobant des concepts scientifiques intéressants pour son propre domaine de recherche.
- Chercheur membre d'une équipe de projet : Qui emploie des concepts et qui interagit avec les autres membres de l'équipe pour traiter une question scientifique commune.
- Administrateur : Qui pourrait modifier l'information contenue dans le système.

Pour chaque utilisateur identifié nous avons construit son diagramme de cas d'utilisation. Ceci nous a permis d'établir les différentes classes qui interagissent dans le système. Ces classes reflètent les éléments qui interviennent dans la recherche bibliographique. En effet, d'après nos observations, celle-ci est menée par des chercheurs dans le cadre des projets de recherche visant à étudier des phénomènes. Pour ce faire, un des aspects importants est la recherche bibliographique qui demande l'identification, l'obtention et l'analyse des documents scientifiques. Lors de l'analyse, le chercheur trouve des zones du document qui lui semblent importants, trouve des concepts scientifiques ayant servi comme base pour traiter la question posée par le document et fait des annotations qui montrent ses opinions, sa pensée, enfin, sa connaissance par rapport aux aspects traités dans le document. En conséquence, les classes identifiées sont :

- Chercheur : Représente les utilisateurs,
- Document : Des documents qui peuvent contenir des concepts,
- Zone de document : Les zones d'un document englobant un concept ou n'importe quelle information considérée comme intéressante par le chercheur,
- Concept : Une définition ou une description d'un concept,
- Annotation : Une annotation[3] au sujet d'une ou plusieurs instances des classes identifiées,

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[3] (Sohn, W.-S., et al., 2003) écrivent : « l'annotation dans un environnement de document se compose du texte rajouté afin de expliquer, de décrire ou de mettre l'accent sur le sujet d'un document (Marshall, 1997, 1998b;

- Projet : Représente le cadre où les instances des autres classes sont employées afin de produire de nouveaux concepts.

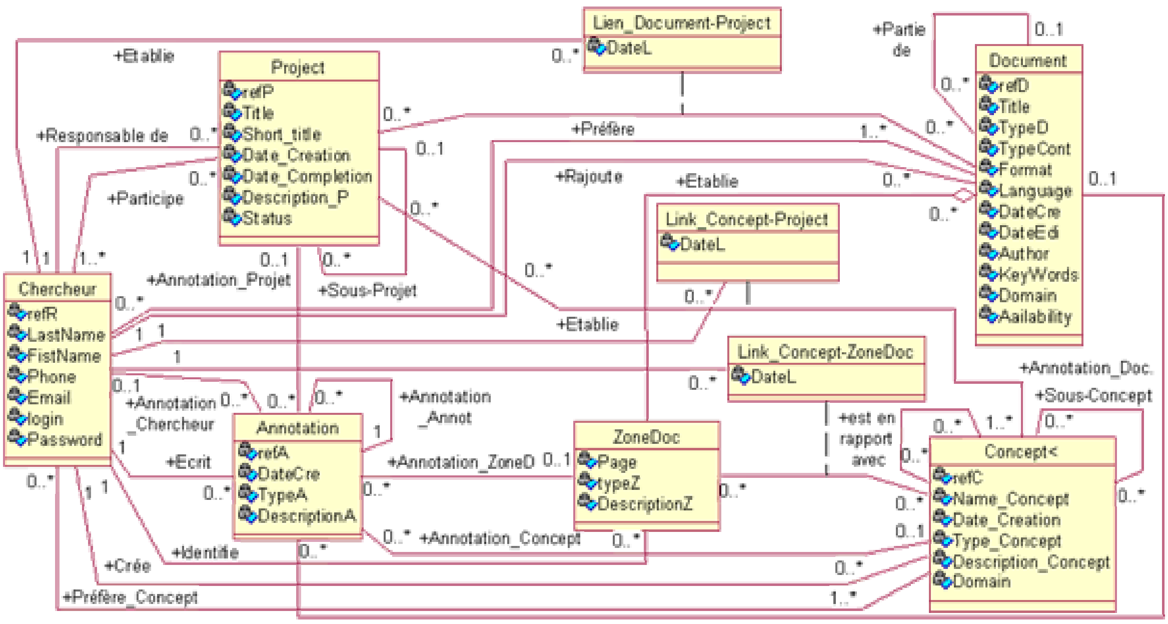

Figure 3. Diagramme de classe pour un système de soutien pour la réalisation du travail bibliographique.

En développant un projet de recherche, les chercheurs emploient ces éléments les identifiant, les choisissant, les intériorisant et les modifiant selon le phénomène étudié par un projet de recherche. Ce processus est représenté par les quelques éléments additionnels qui représentent les liens entre les classes identifiées. Les interactions parmi ces classes sont représentées dans le diagramme représenté sur la figure 3.

Ce modèle nous permet d'établir la base avec les caractéristiques de l'outil proposé. Nous présenterons maintenant les scénarios de l'utilisation que nous avons prévu afin d'arriver à un plus grand degré de détail dans les caractéristiques de l'outil.

Ovsiannikov et al., 1999). Elles sont illustrées avec des types de modèle tels que le soulignage, le symbole, et la note (Marshall, 1997; O'Hara and Sellen, 1997) ».

- Les Scénarios d'utilisation

Nous avons analysé les scénarios au cours desquels l'approche serait probablement utilisée. Pour cela, nous avons commencé par regarder les activités déjà effectuées par des chercheurs lors de la réalisation de la recherche bibliographique, sans aucun outil particulier pour soutenir leur activité. Ceci nous a permis d'identifier huit scénarios :

1. Chercheur recherchant des documents,
2. Chercheur lisant des documents: Identification des concepts scientifiques (études des similitudes avec d'autres concepts scientifiques), études des annotations précédemment faites par d'autres chercheurs, rédaction d’annotations (aux annotations précédentes, au document, aux zones spécifiques de document, aux concepts scientifiques),
3. Chercheur rédigeant des documents : Emploie des concepts, insertion des parties de documents dans d'autres documents, coopération avec d'autres chercheurs, mise en forme du document,
4. Chercheur recherchant des concepts : Recherche des documents englobant des concepts, recherche des projets qui utilisent ou qui ont utilisé un concept spécifique, recherche de chercheurs qui utilisent ou qui ont utilisé le concept,
5. Chercheur développant des concepts : Utilisation des concepts et des documents,
6. Chercheur recherchant d'autres chercheurs : Recherche de chercheurs répondant aux critères de recherche,
7. Chercheur recherchant des projets : Recherche des concepts et des documents utilisés aux différentes étapes d’un projet spécifique, recherche des chercheurs qui participent à son développement,
8. Chercheur participant aux projets : Identification des concepts scientifiques et des documents utiles pour le projet en général ou pour des aspects spécifiques.

Ces scénarios peuvent être illustrés par la figure 4. Cette figure montre les différentes manières dont un chercheur pourrait travailler avec l'outil lors de la réalisation d’une recherche bibliographique. Nous avons également représenté les relations parmi les différents éléments qui apparaissent lors de cette activité : chercheurs, projets, documents, concepts et annotations. Cette analyse, ainsi que les précédentes (la modélisation UML et l'analyse fonctionnelle), nous ont permis de définir les fonctionnalités principales dont l’approche devrait bénéficier pour soutenir les activités des chercheurs.

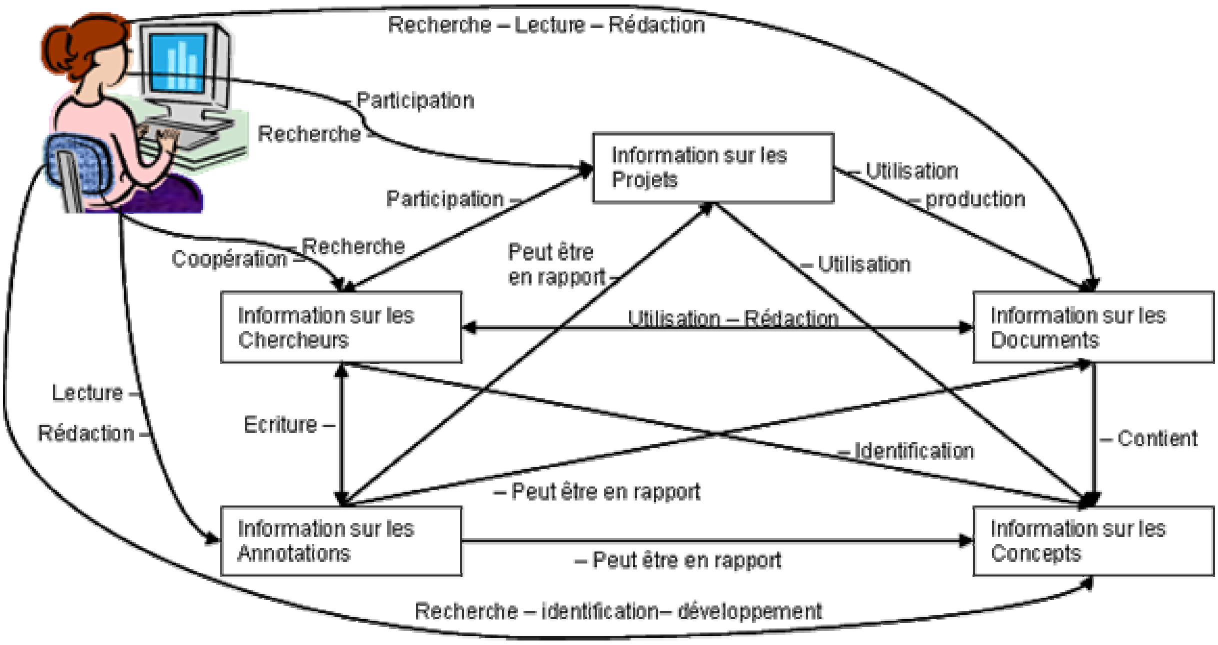

Figure 4. Scénarios d'utilisation d'un outil pour soutenir la recherche bibliographique.

- Les Fonctionnalités de l'approche

Tout d'abord, nous avons défini trois niveaux dans lesquels l'interaction parmi les éléments identifiés peuvent apparaître : à un niveau individuel, à un niveau de projet et au niveau du laboratoire dans son ensemble. Ceci indique qu'un chercheur peut travailler seul ou comme partie d'un projet. Dans ce dernier cas, il peut partager le résultat de sa propre recherche bibliographique et profiter de celles effectuées par ses collègues chercheurs de l'organisation. Cette structure est cohérente avec la position d'(Anell, B., 1998) au sujet des trois niveaux auxquels l'apprentissage doit se produire[4]. À chacun de ces niveaux il est nécessaire de maîtriser les documents, les concepts et les annotations. Pour aider le chercheur dans ces tâches, nous avons identifié les fonctionnalités principales dont il pourrait avoir besoin et nous les avons représentées sous forme de graphes. Sur la Figure 5 nous montrons les fonctions identifiées pour le niveau de projet.

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[4] L'apprentissage selon (Anell, B., 1998) « doit se produire au moins à trois niveaux. Le premier niveau est le niveau individuel... Le niveau suivant est le niveau du groupe... l'apprentissage doit également se produire à un troisième niveau qui est, bien évidement, le niveau d'organisation. Si l'acquisition et le partage de nouvelles connaissances n'imprègne pas l'organisation entière, elle deviendra non équilibrée et ne pourra pas employer les nouvelles connaissances que l'apprentissage a créé ».

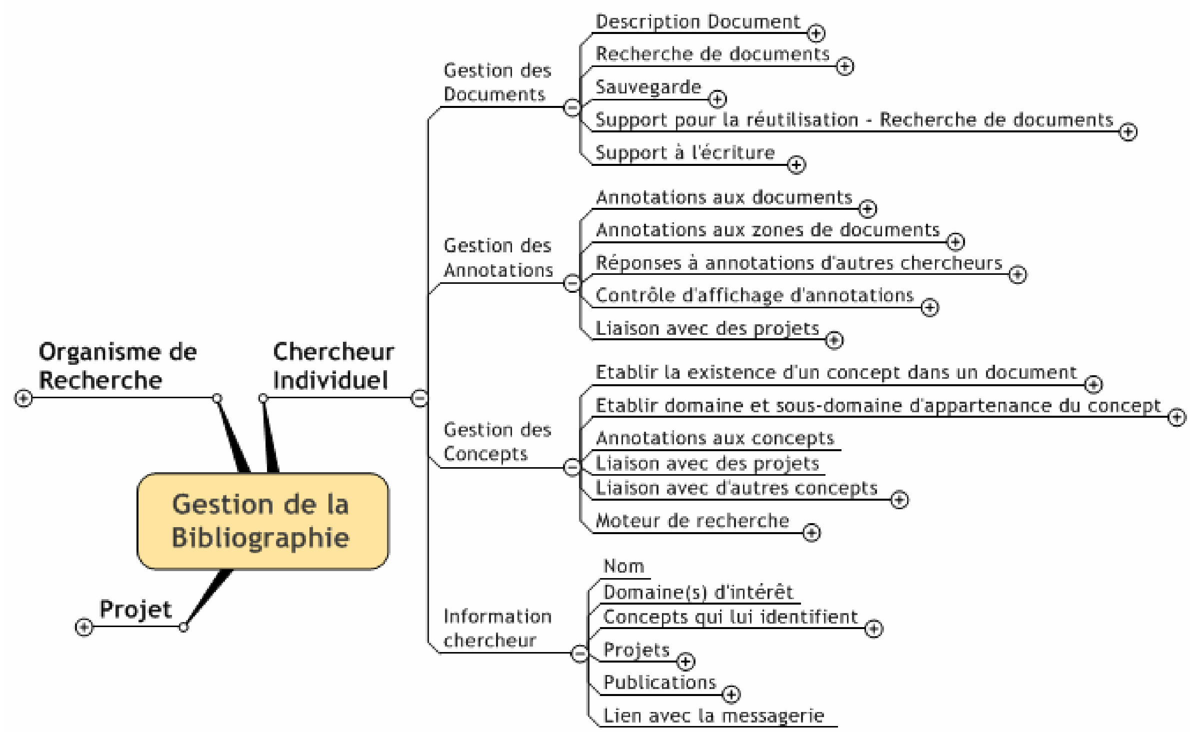

Figure 5. Les fonctionnalités principales de l'outil (Niveau chercheur).

Ces fonctionnalités reflètent quelques principes de base que nous considérons comme importants : l'outil devrait appuyer le chercheur travaillant individuellement, il devrait appuyer le développement des projets de recherche et il devrait améliorer le partage des connaissances entre tous les membres d'une organisation de recherche. En plus, il existe quelques caractéristiques que nous considérons comme essentielles. Elles se déclinent comme suit : flexibilité, facilité d'utilisation, adaptation aux pratiques des chercheurs et facilité d'entretien. Ces dispositifs devraient nous aider à surmonter certaines des barrières qui apparaissent lors de la mise en place d'un nouveau logiciel.

Nous avons établi les fonctionnalités principales, les caractéristiques et les scénarios d'utilisation que l'approche envisagée devrait avoir. L'étape suivante consiste à développer le prototype, qui devrait servir à concrétiser le fonctionnement de l'approche et les possibilités qu'il pourrait offrir aux organismes de recherche.

Le Prototype d'un Outil pour montrer l'Approche Proposée

Pour montrer la façon dont l'approche proposée pourrait fonctionner, nous avons développé un prototype de celui-ci. Dans cette section, nous présenterons les principales spécifications techniques du prototype et les résultats que nous avons obtenus des essais que nous avons faits.

- Les spécifications techniques du prototype

Un des premiers aspects que nous avons défini concernant le prototype est qu'il devrait fonctionner comme un portail. Ceci évite des difficultés d'installation, facilite l'entretien et fournit de la transparence aux utilisateurs (parce que le prototype devrait fonctionner à travers le navigateur d'Internet, indépendamment de la localisation réelle de l'application et des documents potentiellement stockés).

Un autre aspect important est la facilité du développement. A l'étape actuelle de notre recherche, nous souhaitons valider nos propositions en analysant si l'approche proposée pourrait être utile pour les chercheurs. Nous ne visons pas le développement de l'outil final. Ceci, nous l'espérons, sera entrepris dans une étape future. Pour cette raison, nous avons choisi le langage PHP, qui est plutôt simple et rapide à employer et qui a un grand succès pour le développement des applications Web. En outre, beaucoup de serveurs Web, comme Apache ou IIS (le serveur Web de Microsoft), le supportent.

Un autre aspect à analyser est le stockage des artefacts dans le prototype. Pour cela, on utilisera un système de gestion de base de données - SGBD. À cette fin, nous avons choisi MySQL, qui est un SGBD généralement utilisé pour des applications Web. Il propose des fonctionnalités importantes comme : *multi-threaded* (il soutient l'accès de plusieurs utilisateurs en même temps), il supporte des transactions (il permet le rétablissement de données sur des erreurs internes), il peut être facilement intégré avec PHP, il a une consommation raisonnable de ressources de mémoire et il est facile à gérer. La combinaison PHP - MYSQL, a été faite en utilisant EasyPHP, qui installe et configure automatiquement une zone de travail complète. En plus, nous avons employé le Macromedia Dreamweaver MX pour le développement du portail.

Un autre aspect important à résoudre était la gestion des annotations. À cette fin, nous avons profité des fonctionnalités offertes par Adobe Acrobat 5.0 pour ajouter des annotations à un document sous format pdf, car le pdf est le format généralement utilisé pour les documents scientifiques. De cette façon, l'aspect graphique de l'annotation peut être géré avec les fonctionnalités offertes par Acrobat, alors que leur contenu (texte libre) est géré par la base de données. Ceci afin de permettre des opérations telles que l'enregistrement, la recherche, le choix (dans une liste de favoris) et l'établissement des liens parmi les différents artefacts contenus dans la base de données[5]. La Figure 6 montre un des écrans du prototype.

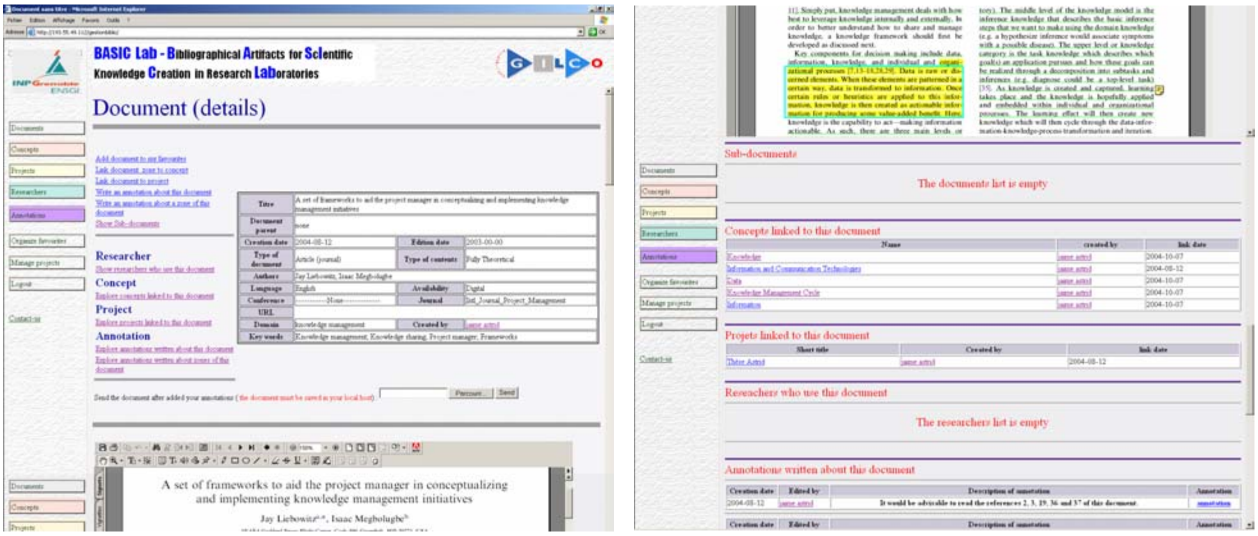

Figure 6. Un des écrans du prototype.

- Le retour d'expériences

Dans son état actuel, le prototype permet d'ajouter des documents et des annotations à une base centralisée, créer des projets et des concepts et définir des zones de document. Ces éléments peuvent être liés entre eux afin de les employer pour un intérêt particulier. Par exemple, un chercheur peut ajouter un document jugé intéressant. Puis, il peut définir les zones des documents considérées comme les plus intéressantes, établir où dans le document se trouvent les définitions ou les explications des concepts scientifiques employés par l'auteur(s) et ajouter des commentaires au document ou aux zones de document. Le chercheur pourrait également choisir quelques éléments à maintenir dans sa liste personnelle de favoris et choisir ceux qui pourraient être potentiellement utiles pour un projet particulier. Les autres membres de l'équipe d'un projet pourraient également inclure d'autres artefacts considérés utiles pour étudier un phénomène, partageant de cette façon une partie de leurs connaissances.

[5] L'utilisation de RDF pour gérer des annotations est envisagée seulement à une phase future du projet, quand le développement de l'outil sera réalisé.

En plus, les éléments dans le prototype sont *hyperlinked* pour faciliter la navigation parmi eux et l'accès aux différents artefacts. De cette façon, nous souhaitons garder dynamiquement la mémoire des projets de recherche à travers la contextualisation (relation entre chaque chercheur, chaque concept, chaque document, chaque annotation et chaque projet) d'une partie des analyses des contenus effectués par les chercheurs.

Actuellement, le prototype est installé sur un serveur, ce qui nous a permis de faire quelques essais afin d'analyser les possibilités qu'un approche comme celui proposé pourrait offrir à un groupe de chercheurs pour exécuter leurs activités.

Afin de vérifier les avantages potentiels qu'une approche, telle que celle que nous proposons, pourrait apporter aux organismes de recherche, nous avons essayé le prototype. La première étape de ces épreuves a consisté en l'introduction de quelques documents, déjà annotés et classés, dans la base de données. Les documents sont un échantillon de ceux utilisés pour le développement de notre projet. La plupart d'entre eux appartiennent au domaine du KM. Un groupe d'étudiants de troisième cycle a participé aux épreuves. Un étudiant de Doctorat et trois étudiants de maîtrise ont constitué le groupe. Ils travaillent tous sur des sujets liés au KM. Pour cela, nous avons pensé qu'ils pourraient être intéressés à explorer le contenu déjà enregistré dans le prototype. Une première session a été tenue afin de présenter le prototype et les fonctionnalités principales. Après celle-ci, ils pourraient accéder au prototype en tout moment, comme appui à leurs projets. Etant donné que le prototype trace les actions faites par chaque personne en ajoutant l'auteur et la date de chaque action, nous nous sommes appuyés sur cette fonctionnalité pour suivre l'utilisation qu'ils ont fait du prototype.

Après une période de quatre semaines, nous avons observé une utilisation faible du prototype. Par conséquent, nous avons interviewé les membres du groupe pour connaître les raisons de ce comportement. Leurs réponses prouvent que bien qu'elles trouvent le prototype intéressant et les fonctionnalités utiles, ils ne veulent pas investir le temps nécessaire pour l'entrée de nouvelle information dans le prototype. C'est ce qui est connu comme le « goulot d'étranglement de capture » (*« capture bottleneck »*).

Compte tenu des résultats de cette première étape, nous avons procédé à une deuxième étape où nous avons fait différentes présentations du prototype à un groupe de 10 chercheurs. Nous les avons alors interviewés concernant les fonctionnalités mises en application. Leurs réponses vérifient la nécessité d'un meilleur appui au travail bibliographique et la convenance des fonctionnalités mises en application et en général de l'approche proposée dans le prototype.

Conclusions et Perspectives

Au cours de ces travaux, nous nous sommes intéressés aux organismes de recherche, en tant qu'établissements dédiés à la production de nouvelles connaissances. Pour étudier l'utilisation du KM, nous avons effectué un travail de terrain afin de connaître l'utilisation des pratiques formelles de KM dans un groupe d'organismes de recherche. Nous avons observé une utilisation faible de ces pratiques et un accent sur la capitalisation des résultats finaux obtenus à partir des activités de recherche (et pas sur les résultats intermédiaires ou des artefacts). Or, nous avons remarqué l'importance de la capitalisation des connaissances produites et acquises pendant la réalisation d'un projet, c'est-à-dire, la capitalisation des artéfacts produits.

La schématisation du déroulement des projets de recherche réalisée nous a permis d'identifier trois catégories d'artefacts : les artefacts liées à la bibliographie, ceux liés à la gestion du projet et ceux liés aux résultats intermédiaires. Les outils méthodologiques et les outils informatiques que nous avons identifiés ne facilitent pas la capitalisation des artefacts bibliographiques. Etant donné le caractère transversal du travail bibliographique, nous avons décidé de travailler sur la définition d'une approche focalisée sur la gestion des artéfacts produits lors de la réalisation de la recherche bibliographique. Nous avons établi les spécifications essentielles de l'approche, principalement à travers la modélisation du système avec UML et une analyse de scénarios d'utilisation. Nous avons employé ces éléments pour développer un prototype de l'approche. Nous l'avons essayé et avons constaté les possibilités qu'il offre aux chercheurs pour la gestion et la capitalisation du travail bibliographique effectué dans le cadre d'un projet de recherche. Nous espérons poursuivre son amélioration afin qu'il puisse offrir aux chercheurs un support pour la gestion et la capitalisation d'au moins une partie des connaissances acquises et produites pendant la réalisation de cette activité bibliographique.

Introduction

> "The saying that knowledge is power is not quite true. Used knowledge is power, and more than power. It is money, and service, and better living for our fellowmen, and a hundred other good things. But mere knowledge, left unused, has no power in it." Edward E. Free

General context of the dissertation

Several authors, institutions and even governments have claimed the importance of research activities. This importance comes from the benefits that may emerge from them. Thus, some scholars have recognized the benefits generated by publicly funded basic research (Salter, A.J., Martin, B.R., 2001), mainly in terms of an increase in "the stock of useful knowledge" (Salter, A.J., Martin, B.R., 2001) for innovation and economic growth (Tijssen, J.W., 2004).

According to (Nelson, R. R., 2004), the technological progress is largely dependent on the science base that supports it, which, at the same time, is an important part "the product of publicly funded research." Some scholars, such as (Meyer, M., 2000), have analyzed elements like patent citations to show the contribution of science to technology. Similarly, some scholars have stressed the important role of publications in the acceleration of the flow of information regarding scientific knowledge, which, in turn, "may stimulate the rate of technological innovation" (Sorenson, O., Fleming, L., 2004; Nelson, R. R., 2004).

(Zellner, Ch., 2003) expresses a different point of view. According to him, the wider benefits obtained from publicly-funded basic research are related to the migration of scientists into the innovation system. Furthermore, (Zellner, Ch., Fornahl, D., 2002) claim that firms can acquire scientific knowledge through three main channels: recruiting, informal networks and formal cooperation. These channels allow scientists to contribute knowledge regarding the following: scientific discipline, scientific facts and theories, laboratory techniques, instrumentation and laboratory equipment and analytical skills for the solution of problems (Zellner, Ch., Fornahl, D., 2002). Similarly, (Nelson, R. R., 2004) sees these contributions in terms of the knowledge and the tools necessary to wrestle with practical problems more effectively. In addition, (Murray, F., 2004), says that the contribution of scientists happens at two levels: human capital (scientific knowledge, knowledge of laboratory techniques and expertise in developing scientific strategy) and social capital (scientific network). Nevertheless, (Pavitt, 2002) notes that the "effective absorption (i.e. replication) of research results [by companies] from elsewhere requires a minimum threshold of investment in research skills, equipment and professional networks." Complementarily, (Meyer, M., 2000) notes that, in some cases, "technology can drive science, too".

Though the benefits emerging from science may not be direct, they have been recognized as important for the improvement of the well-being of society. For that reason, it is not uncommon to see works stating that "the leading edge of the economy in developed countries has become driven by technologies based on knowledge and information production and dissemination" (Powell, W. W., Snellman, K., 2004). In this context, the role of basic science for economic growth seems to have increased in countries such as the United States, given the rapid growth observed in university patenting (Powell, W. W., Snellman, K., 2004). This could be one of the facts explaining the growing interest in the scientific activities (Erdelen W., 2004).

In addition, other aspects have come to form part of the actual dynamics in the scientific domain. Thus, we have noticed mainly the movements around quality management in research organizations. This aspect presents two faces: On the one hand, the publications made by different organizations proposing the implementation of QMS in research organizations. On the other, the current experiences of implementation of quality management systems – QMS in some research laboratories. For that reason, we are interested in studying the experiences of implementation of QMS in some research laboratories.

Nevertheless, research organizations are particular organizations playing a central role in the advancement of science. The latter is, according to some scholars, "a system of knowledge" (Nelson, R. R., 2004). This is consistent with the etymological origin of the word science, which has its origins in the Latin verb *scire*, meaning "to know" (Malhotra, Y., 1994). Thus, it seems reasonable to think that in order to support a knowledge-intensive activity, the methods and tools issued from the knowledge management domain be used. The latter has shown a growing importance among the scientific community, which has proposed a great amount of works on knowledge management.

For that reason, our interest in the QMS in research organizations aims at analysing if these processes lead to the implementation of knowledge management practices. The hypothesis is that when implementing a QMS at a research organization, an important part of the project should be focused on the definition of mechanisms to support the research activity, the one aimed at the production of knowledge. Thus, we are interested in research organizations as organizations producing knowledge and we focus on organizations implementing a QMS. For that reason, we will now explain some aspects related to our subject of interest.

Subject of Interest

The expression "knowledge economy" is used to represent the "production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence" (Powell, W. W., Snellman, K., 2004). In it, the key components include "a greater reliance on intellectual capabilities than on physical inputs or natural resources, combined with efforts to integrate improvements in every stage of the production process, from the R&D lab to the factory floor to the interface with customers" (Powell, W. W., Snellman, K., 2004).

This explains our interest in the scientific activities. In fact, they are seen as one important stage in the production process. Moreover, we are interested in research activities as activities devoted to the production of knowledge. More precisely, we are interested in basic research activities[6]. These are defined as the "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts,

[6] According to (Branscomb, L., Holton, G., Sonnert, G. (2001): "Basic scientific research is a concept popularized by Vannevar Bush in Science the Endless Frontier. Bush believed the creativity of basic science would be lost if it is constrained by premature thought of practical use, a concern that motivated the sometimes challenged distinction between basic and applied research. Many authors prefer "fundamental research" (to characterize its outcomes as contributions to understanding of nature), or "creative research" (to describe the conditions under which it is performed) over "basic research" (emphasizing the curiosity-driven motivation)." In this work, we will use these expressions indistinctively.

without any particular application or use in view" (OECD, 2002). It differs from the applied research, where "a specific practical aim or objective" is defined (OECD, 2002). According to (Nelson, R. R., 2004), an important difference is the motivation to endeavour in research. Thus, while the motivation in scientific research is the "failure to understand why something works", technological research "is concerned with achieving practical ends." However, we acknowledge the fact that "the lines between basic science and applied science are fuzzy not sharp" (Nelson, R. R., 2004) and that "performing more applied research does not necessarily imply a trade off with basic research" (Van Looy, B., et al., 2004).

Thus, we are interested in those research activities characterized as being highly unpredictable and whose development is, therefore, hard to support through standardized practices. These activities are mostly developed in academic research laboratories. For that reason, we study these organizations in order to understand their functioning and the way in which research activities are carried out. As one of the common practices used by research organizations is to structure the activity in projects (Vinck, D., 1995), we are particularly interested in finding ways of supporting the production of knowledge through the realization of basic research projects.

Consequently, our approach has been to focus on the management of the activities done by the research laboratories. We have chosen to concentrate on the activities done within the limits of the individual laboratories. Thus, the interactions among scientific networks are not taken into account. Furthermore, our interest is the research laboratory as an organization whose objective is the production of knowledge. Hence, we concentrate on the activities leading to the production of knowledge, and try to propose mechanisms for supporting them.

For that reason, we are interested in the possibility of using knowledge management for this purpose. In this sense, we make a distinction between the daily activities of a research laboratory and those belonging to the field of knowledge management. This means that we distinguish the activities aimed at creating knowledge, notably the scientific activities, from those aimed at supporting them through the implementation of means to capture, capitalize and re-use knowledge.

Accordingly, we lean mostly on the knowledge management literature, which has *been* developed greatly during the last few years, and proposes mechanisms for supporting the realization of activities. Therefore, we have chosen to limit the scope of the analysis to the knowledge management domain, which means leaving the use of the literature coming from other, more analytically focused, domains (such as knowledge sociology, epistemology, philosophy of knowledge, cognitive science) for a future stage. This means that we lean on the literature aiming at proposing ways for managing knowledge rather than on the literature aiming at providing conceptualizations about the nature of knowledge.

Contributions

We propose an approach for capitalizing a part of the knowledge used and produced through the development of research projects aimed, at the same time, at supporting researchers on the management of bibliographic contents. This proposal is the result of the study of the reality of research organisations. A special focus has been put on the research organizations working on the implementation of quality management systems. Our first hypothesis was that this implementation would require using knowledge management methods when applied to research activities. However, our observations have not verified this hypothesis. On the contrary, they have shown that the quality management systems we have observed concentrate on the activities supporting the research activity, but hardly on the research activity itself. Hence, we have not been able to make observations regarding the implementation of knowledge management methods in research activities (linked to the quality management systems being implemented).

For that reason, we proceeded to analyse the way research activities are done and propose a model of the development of research projects, based on the study of some social sciences literature and on our own observations. This model differentiates between routine, semi-routine and non-routine activities. This shows the presence of routine activities even in the framework of activities considered non-routine on a global level. This is important because we can expect to find ways of supporting routine activities. In addition, the model allows us to identify the artifacts used and created during the development of research projects. The study of these artifacts leads us to classify them in three types: artifacts related to the bibliography, artifacts related to the management of the project and artifacts related to the intermediate results.

In order to find ways to capitalize these artifacts, we analyze the methodological and the software tools. Given the non-adaptability of the methodological tools to the research context, the lack of software tools supporting the management of the bibliographical artifacts and the transversal character of the bibliographic research regarding the different research domains, we decided to concentrate on the capitalization of bibliographical artifacts.

For this reason, it was necessary to study the scientists' practices regarding the bibliographical artifacts. We used three main sources for defining these practices: scholarly documents, direct observation of our laboratory colleagues and our own experience. The insights obtained through these sources have allowed us to identify five basic elements participating in the bibliographical research: Researchers, Documents, Annotations, Concepts and Projects. This means that this kind of research is done through interactions among scientists, between scientists and bibliographical artifacts and between the bibliographical artifacts themselves. Thus, the bibliographical research is seen as a series of interactions between these elements. Consequently, supporting this process requires facilitating researchers to manage these interactions. To achieve this, we propose an approach that simultaneously facilitates this activity, while preserving a memory of the bibliographical work done in the framework of the research projects developed, and promoting, in this way, its sharing and re-utilization. Thus, the capitalization of knowledge is achieved through the capitalization of artifacts and also through the facilitation of direct interactions among the scientists belonging to the same institution.

Methodology

The methodology used for the development of this work shows the interdisciplinary nature of it. Thus, we started by using a sociological approach that is later coupled with the use of engineering tools. This work has been complemented by the definition of some proposals and has several phases:

- Study of literature: In this phase, we study the bibliographical sources we consider relevant for our subject. We mostly rely on literature originated on social studies of science, quality management and knowledge management.
- Field work: This phase consists of a sociological work performed in several stages.
    - Observation of the normal operation of a research organization for four months.
    - Interviews with the people responsible for quality management at seven research organizations where formal efforts of introduction of this methodology are being carried out.
    - Follow-up study of the implementation process of the quality system at a research laboratory during 18 months.
- Analysis of the information gathered and development of an approach: This analysis consists of the utilization of engineering methods in order to develop a proposition aimed at improving the realization of research activities.
- Development of a prototype of a computational tool: Based on the analyses made, we present the specifications of an approach aimed at supporting researchers during the development of their activities and, at the same time, capitalize at least part of the knowledge produced. In order to show how this approach could function, we developed a prototype of a computational tool materializing the approach proposed.
- Tests of the prototype of the tool: The objective of this phase is to verify if the approach proposed is well adapted to the reality of research organizations and to the scientists' practices.

The application of this methodology is reflected in the structure of the document. In the next section we will explain this structure.

Structure of the document

This work is organized in three parts. In the first one, we present the theoretical bases of the work, together with our observations regarding the different aspects we present. In order to facilitate the reading of the document, we have signalled the paragraphs concerning our observations by placing a vertical line on their right side (such as the one we have placed on the right side of this paragraph).

Three aspects are included in this part. As our subject of study is the research activities, we start by a presentation of some aspects we consider fundamental about science. Then, given that we started by analyzing the impact the implementation of quality management systems would have on the research activities, we present some basic concepts about quality management, together with our observations regarding the implementation of these systems. Finally, since our interest in research activities focuses on the production of knowledge, we present some basic concepts belonging to the knowledge management domain. We also present our observations regarding the impact the quality management system has had on the management of the scientific knowledge at the observed institutions.

In the second part of this work, we present the problem we want to study, given the situation in the research organizations we have observed. We position our work within the literature proposing approaches dealing simultaneously with quality management and knowledge management issues. Then, we analyze the situation we have observed in order to concretely define the aspect on which we will focus. Thus, after studying the methodological and software tools proposed for the management of knowledge, we decided to concentrate on the management of bibliographical artifacts. For this purpose, we propose to define the specifications of an approach that supports scientists during the bibliographic research, as a way of capitalizing at least part of the knowledge acquired and produced during the development of research projects.

In the third part, we propose an approach for capitalizing bibliographical artifacts. The proposition is presented in three chapters. In the first one, we present the basis for the definition of the specifications of the approach. This basis is mostly the current scientists' practices regarding the bibliographic artifacts. These practices are used to define the basic requirements of the approach. Then, in the second chapter of this part, we do some analyses leading to the specifications of the approach. Finally, in the last chapter of this part we present the prototype of a tool materializing the approach proposed and the feedback we have received from the people to whom we have shown it.

The last chapter of the document presents the general conclusions of the work and the perspectives we envision for the future.

Part 1. Theory and Observations

Chapter 1. Science

> "Scientists… have to devote themselves to normal scientific research in order to be aware of anomalies. Even when they deal with anomalies from a revolutionary viewpoint, they cannot help using the existing concepts and terms." (Noé, K., 1998)

1.1 Introduction

The scientific activity in its quest for producing new knowledge (see Chalmers, A., 1991; AFNOR, 2003) demands important resources, such as highly skilled people, time and financial resources. The benefits obtained from this activity are particularly difficult to define in the case of basic research where many of its achievements may be perceived, at first glance, as being distanced from social issues. However, (Martin et al., 1996) present the benefits of publicly funded research as:

- increasing the stock of useful knowledge;
- training skilled graduates;
- creating new scientific instrumentation and methodologies;
- forming networks and stimulating social interaction;
- increasing the capacity for scientific and technological problem-solving; and
- creating new firms.

Some of these benefits have been also reported by other authors (See Mansfield, 1991; Mansfield, 1998; Salter, A.J., Martin, B.R., 2001 and Rosenberg, 1992). Other works focus on the benefits for firms (See Salter, A.J., Martin, B.R., 2001; Hatchuel, A., Weil, B., 1999; Weaver, W., 1948). Firms can use the knowledge produced by basic research for improving their processes and products, bringing in this way benefits for society. The position expressed by (Salter, A.J. and Martin, B.R., 2001) is particularly strong regarding the economic benefits produced by basic research. They assert that these benefits are substantial and appear in different forms and argue that the question is "how best to organise the national research and innovation system to make the most effective use of them."

Thus, whatever the benefits are, it is important to support basic research to continue counting on them. One way of doing it is to support it at the macro level, as (Salter, A.J. and Martin, B.R., 2001) propose. This means searching for better ways to organise networks, foster synergies and promote exchanges. Several organizations and initiatives around the world exist for this purpose[7]. On the other hand, our aim is to support the research activity at the micro level. This means, proposing ways for improving the organization of research inside individual organizations. For that reason, we are interested in finding ways to support the research activities.

In this chapter, we present some important aspects that the social sciences have defined about science and our own observations relating to the way research organizations perform their activities. The first part of the chapter corresponds to theoretical aspects regarding the definition of what science is, the elements involved in the construction of facts and the use of bibliographical documents in the scientific activity. Then, in the second part, we present some of the main aspects we have observed about the theoretical aspects presented. We finish by stating the main conclusions of the chapter.

1.2 The theoretical claims regarding Science

1.2.1 What is science?

The first aspect to clarify is the object of our interest. In this sense, different positions exist regarding science. (Weaver, W., 1948) sees science as solving problems "in which the prevalent factors are prone to the fundamental laws of logic, and are for the majority measurable." From his point of view, science has to be reproducible, impartial and based on facts on nature. While some people will find this view of science as well-fitted to reality,

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[7] An example of these initiatives is the ERA-NET scheme, the objective of which is to "to step up the cooperation and coordination of research activities carried out at national or regional level" (see http://www.cordis.lu/coordination/era-net.htm). Another example is the EUROCORES Scheme (EUROpean Science Foundation COllaborative RESearch), which is a "mechanism for multinational collaboration within Europe in basic research" (see http://www.esf.org/esf_activity_home.php?language=0&domain=0&activity=7).

others will argue quite the contrary. The latter, consider this view as completely un-realistic because it disregards the importance of the role played by the social context in the scientific arena (Chalmers, A., 1991).

Popper, K. R. is maybe the most representative author defending the importance of the social context and the impossibility of proving scientific theories. He claims that it is impossible to prove the truthfulness a theory, and that it is only possible to prove that a theory is false. He questions the statements based on observation because theory influences observation. In addition, he asserts that the context plays an important role for the acceptance or the rejection of results obtained through observation and experimentation. Furthermore, he observes that knowledge "is a social product that results from the modification of preliminary knowledge and is not established in a direct confrontation with the physical world (Popper, 1979, p. 71)" (Chalmers, A., 1991)

We observe here two extreme points of view regarding science: the first one, where everything in science is completely clear and straightforward, and the second, where nothing can be really proven since it is a "social product". Our position is in the middle of these extremes because we believe that scientists strive to present facts, even though the social and the historical context exert an influence over the scientific production (Chalmers, A. 1991)[8]. In order to define our vision of science, we will explore some of the characteristics of the scientific activity.

1.2.1.1 Some characteristics of the scientific activity

The scholars working on the study of science have provided some important observations regarding the nature of this activity. These observations give us valuable insights regarding fundamental characteristics of the activity. We will now present some of them.

[8] We clarify that we do not intend to enter into the debate about the rational or social character of science, but to express our position regarding the activities we want to support. Such a debate is out of the scope of this work.

- *Science as knowledge production*

One of the main characteristics of the scientific activity is its product. For (Kuhn, T. S., 1996) the scientists try to increase the precision and the scope of their understanding of the world. This means that the result of the activity is scientific knowledge represented in publications, instruments and people (Vinck, D., 1995; Chalmers, A., 1991).

- *Science as a cumulative process*

(Chalmers, A., 1991) remarks that modern science aims at better predicting facts, and not to rightly predicting them. Thus, science is an improvement or continuous growth process aimed at producing new theories for successfully predicting new facts. This improvement process of theories indicates that science is a cumulative process. This means that, in their effort to present the facts, scientists build on the work previously done by other scientists, increasing the capacity to explain phenomena. For (Kuhn, T. S., 1996) scientific development is a process of adding, singly and in combination, “facts, theories, and methods” to “the ever growing stockpile that constitutes scientific technique and knowledge.”[9]

- *Science as a collaborative process*

(Kuhn, T. S., 1996) explains that the production of a new theory is an activity that is “seldom completed by a single man”. Accordingly, (Vinck, D., 1995) explains that “the scientific activity is composed of projects” and that “meanings are built through interactions and collective action.” Also, (Giere, R. N., 2003) reminds us that social interactions are at the origin of human cognition and therefore “the production of modern scientific knowledge is more the product of a particular form of scientific culture than that of individual scientists.” This implies that science is a collaborative process that demands the participation of several people interacting in the framework of projects.

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[9] (Kuhn, T. S., 1996) notes the existence of “scientific revolutions”, and defines them as “those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one.” These scientific revolutions are different from “normal research, which is cumulative”.

1.2.1.2 Our vision of science

We have seen three basic characteristics of the scientific activities. They contribute in an important way to our conception of science as a non-completely inductive process, influenced by context. Our observations regarding engineering research, which studies phenomena belonging to the artificial world, make us move away from completely naturalistic positions such as the one of (Chalmers, A., 1991). Consequently, we propose a definition of science, which we will use as the basis of our work:

> *Science is a quest that aims at increasing the knowledge available about the natural and artificial world through a cumulative and collaborative process, embedded in the social and the historical context where it is done.*

In this sense, what interests us is what (Kuhn, T. S. 1996) calls "normal science". This science is based upon past scientific achievements, the accepted paradigm, and aims at extending the knowledge on certain facts. This means that normal science "aims to refine, extend, and articulate a paradigm that is already in existence." It is then the everyday science, the one mostly practiced by researchers, which differs from the "scientific revolutions"[10] history usually reports. In normal science, the activity consists of bringing "theory and fact into closer agreement, and that activity can easily be seen as testing or as a search for confirmation or falsification." (Kuhn, T. S., 1996). The result of the activity is the production of new theories that contribute to the scientific constellation of accepted facts. (Latour, B. and Woolgar, S., 1986) call this process the construction of facts, which constitutes the basis of the scientific activity. In the next section, we present how these facts are constructed by presenting the activities involved.

1.2.2 The aspects involved in the construction of facts

According to some of the works on science, there seems to exist three important aspects involved in the construction of facts. These aspects are the acceptation of a paradigm, the production of order out of a "disordered array of observations" and the exchange of information with fellows (Latour, B. and Woolgar, S., 1986). The first one, the acceptation of

[10] (Kuhn, T. S., 1996), defines scientific revolutions as "those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one."

a paradigm, demands knowing the theories that have already been validated by the community, while the second, implies the realization of observations and requires instrumental capacities for observing and performing tests about a phenomenon. The results obtained through these activities are intertwined through the interactions of researchers in order to produce new facts, which are reflected in new texts (Latour, B. and Woolgar, S., 1986). Thus, we can see how this construction of facts can be used as a framework for defining the aspects involved in the scientific activity. We will hereafter examine these aspects.

1.2.2.1 From the acceptation of a paradigm to the development of new concepts

According to (Kuhn, T. S., 1996)[11], during a period of "normal science", the construction of facts involves accepting a paradigm on which the scientific work will be based. The facts defined through the activity can be represented through new concepts that may either reinforce the paradigm in place or provide the bases for a new one. These two aspects, accepting a paradigm and developing new concepts, are, therefore, fundamental for the scientific activity. For that reason, hereafter we explore both of them.

- *The acceptation of a paradigm*

According to (Kuhn, T. S., 1996) what a person sees depends, on not only what he looks at, but also on what his previous "visual-conceptual experience has taught him to see." This means that what we see depends on our conception of the world, which is defined by the paradigms we accept as true. For scientists, this means that before observing a phenomenon, they have a certain conception of it, which allows them to gather data for studying it.

This conception of a phenomenon involves acknowledging the previous scientific knowledge related to it. This entails knowing the theories and statements produced in the domain. (Kuhn, T. S., 1996) explains that the appearance of new theories requires the reconstruction of previous theories and the re-evaluation of previous facts. This means that even when scientific

[11] Kuhn's book, The Structure of Scientific Revolutions, was initially published the University of Chicago Press in 1962 (see http://www.emory.edu/EDUCATION/mfp/Kuhnsnap.html). The 1996 version corresponds to the third edition of this book.

products are accepted, the quest for better representations of the phenomena of the world will lead to question the ones in place, carrying out new research activities in order to produce new knowledge (Kuhn, T. S., 1996). Therefore, acknowledging previous knowledge is a hard task. It requires analyzing the extensive literature nowadays produced by scientists for presenting the theories, statements or concepts related to a phenomenon. Furthermore, it requires taking into account the validation (or rejection) the scientific community does regarding these theories, statements or concepts.

- *The development of new concepts*

For (Chalmers, A., 1991) the emergence of new knowledge responds to "problems arising to the former knowledge." For him, the comprehensibility of new theories requires the use of "the existing concepts, modifying them or extending them by analogy to other existing concepts". He adds that the utility of the new concepts requires that they offer "the possibility of new research." Similarly, (Latour, B. and Woolgar, S., 1986) present the activities of a laboratory as a constant performance of "operations on statements; adding modalities, citing, enhancing, diminishing, borrowing, and proposing new combinations." In consequence, the construction of new knowledge leans on current knowledge, which is expressed by scientific concepts that evolve, as new researches are undertaken. Therefore, scientific concepts show the evolution of the knowledge produced by researchers and are at the heart of the activity.

According to (Kuhn, T. S., 1996), scientific concepts present some characteristics. Among them, we find their dependence on context, their limited scope of application, the decision-taking process they imply and the approximate representation they furnish of facts, representing, in this way, scientific knowledge. These characteristics, together with the other literature we have studied[12], have allowed us to establish our understanding of what scientific concepts are. Consequently, we propose defining them as follows:

> *"Scientific concepts are the constructions based on previous scientific knowledge and supporting data, that undergo an evaluation procedure to verify their ability to explore, explain, describe, predict or influence a phenomenon."*

[12] See, for example: Young, N. (2001)

Then, the goal of the scientific activity is to produce new scientific concepts that fit reality better than the previous ones. The manipulation of scientific concepts is the central element of the activity. Experiments and inscriptions are the means for performing this manipulation. For that reason, we will explore the role of experiments in the scientific process.

1.2.2.2 The realization of experiments

One of the central activities in some fields of science is the realization of experiments that allow analyzing a phenomenon in detail. The role of these experiments can be seen from different points of view. Therefore, the first aspect we will explore is their role in the scientific activity. Then, we will explore the manipulation scientists do of experimental results in order to contribute to the construction of new facts.

- *The role of experiments in science: exploring, supporting or rejecting statements*

Experimentation and observation are the usual methods employed by scientists for scrutinizing some aspect of nature in "great empirical detail" (Kuhn, T. S., 1996). However, this scrutiny is seen in two ways: First, it is used to observe a phenomenon and then to obtain results for supporting a theory, and second, it is used to reject a theory. The first way proposes that experiments are a way of proving a theory, while the second sees them as a way of denying a theory. The fact that experiments cannot be exhaustive in terms of the potential cases that could possibly exist makes it necessary to define exactly the scope of a theory and even in this case, being exhaustive is almost impossible (Kuhn, T. S., 1996; Chalmers, A. 1991).

For this reason, some authors consider that "a succeeding test result is a result that 'breaks' the theory" (Bénel, A., et al., 2002). This means that a test is an experiment that can make the theory turn false[13]. However, the scientific character of a theory depends on its testability. The tests must be repeatable and based on test protocols validated by the scientific community. Therefore, tests have a twofold character, they can support a theory or "break" it. For

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[13] The position of Bénel, A. et al., 2002 is based on two important works:

- Popper, K.R. Objective Knowledge: an Evolutionary Approach. Clarendon Press, 1972.
- Kühn, T.S. The Structure of Scientific Revolutions. University of Chicago Press, 1962.

(Chalmers, A., 1991), experiments serve both as empirical demonstrations of a theory and, at the same time, as rejection of previous experimental results. There exist different reasons for rejecting previous results. They vary from errors in the execution and use of outdated methods to lack of relevancy for a problem. Thus, the empirical demonstrations provided by the experimental results are only temporarily valid. Therefore, the scientific bases provided by experimental tests are not as solid as once thought. This does not mean that experimentation is not important for the scientific activity, but quite the contrary, that it is necessary to consider cautiously its results, given their central role for the scientific production. In fact, the use of experimental results for supporting or rejecting theories requires manipulating these results in order to be able to arrive to possibly valuable conclusions. We will explore this aspect hereafter.

- *The manipulation of experimental results*

The manipulation of experimental results involves mainly two aspects: An analytical work aimed at organizing the data and a manual work leading to the production of inscriptions. We will now explore each of these aspects.

  - The production of order out of observations

The realization of experiments or of observations, gives as a result a series of data. Therefore, an important aspect in the construction of facts is the processing of the data gathered. This is what (Latour, B. and Woolgar, S., 1986) call the production of order out of a "disordered array of observations". For (Kuhn, T. S., 1996), scientists try to organize their experimental results through the grouping of "objects and situations into similarity sets." The process is cyclic as it may require, and it usually does, a refinement of the observational techniques and/or a "further articulation of … theories." Therefore, the production or order is a process where scientists try to gather reliable data and to organize it by taking into account the accepted theories in a non-linear process aimed at representing a phenomenon.

An important aspect of this process is the production of inscriptions. These inscriptions support the analytical work done by scientists. Therefore, in the next section we explore some aspects regarding the role they have in science.

- The production of inscriptions

One of the prominent studies of the scientific activity was done by (Latour, B. and Woolgar, S., 1986) who observed the work of neuroendocrinology scientists. They explain that the experimental activity is transcribed into inscriptions that represent the results, allowing a more easy analysis. Consequently, scientists will only handle these inscriptions thereafter, leaving the material dimension of the activity behind them (at least, while no further experiments are necessary). This manipulation of inscriptions is, therefore, fundamental for the progress of knowledge and represents a central activity of the scientific practice.

The inscriptions can take the form of documents that a research team produces and uses while studying a phenomenon. They allow pursuing the study of a phenomenon. That is why scientists seem like "a strange tribe who spend the greatest part of their day coding, marking, altering, correcting, reading, and writing" (Latour, B. and Woolgar, S., 1986). According to these authors, the activity of a laboratory can be understood in terms of the "continual generation of a variety of documents". Similarly, (Vinck, D., 1995) presents the scientific work as a production of inscriptions that are gathered, compared and confronted in order to produce new inscriptions. Some of these new inscriptions will take the form of formal communications, a few of which will be published, allowing fellows to scrutinize the results and to enhance or detract from the status of a statement (Latour, B. and Woolgar, S., 1986). According to (Jacob, F. et al., 2004), the rigorous evaluation of the scientists' production has as counterpart the liberty granted for the production of inscriptions. Thus, the inscriptions are a way of keeping track of the work done and of exchanging information with fellows. However, there are other forms of exchanging information and knowledge. We will explore the role of these exchanges in the next section.

1.2.2.3 The exchange of information and knowledge with colleagues

Another very important aspect in the construction of a fact is the exchange of information and knowledge with fellows. This exchange may, and generally does, take the form of informal communications (Latour, B. and Woolgar, S., 1986). These exchanges support the sharing of information and knowledge among colleagues, allowing group members to continuously profit from each other's knowledge and expertise. In addition, these exchanges help to retrieve relevant practices, papers, and ideas from the past. Although informal communication occurs more frequently than formal communication, informal exchanges focus on the substance of formal communication (Latour, B. and Woolgar, S., 1986; Wenger et al., 2002). The latter is presented as "an *a posteriori* rationalization of the real process" (Latour, B. and Woolgar, S., 1986). It includes publications and any other way of formally sharing scientific results, such as the physical objects that circulate among researchers (Vinck, D., 1999). They allow sharing scientific achievements outside the limits of a research institution. For that reason in the next sections, we will explore the role played by publications and by artifacts for the exchange of information and knowledge.

- *The role of publications*

Publications are the result of the construction of facts (Latour, B. and Woolgar, S., 1986) and collect the "facts, theories and methods" contributed by scientists (Kuhn, T. S., 1996). They are a form of formal communication (Latour, B. and Woolgar, S., 1986) that intends to make scientific knowledge public (Giere, R. N., 2003). These formal communications are defined as "highly structured and stylised reports epitomised by the published journal article" (Latour, B. and Woolgar, S., 1986). The objectivity of the publications seems to be questioned by some scholars. Thus, for (Latour, B. and Woolgar, S., 1986) publications are a means of rhetorical persuasion that present facts as "unconstructed by anyone" and resulting almost exclusively of the "thought process" related to the facts, without any influence of economics, beliefs and circumstances within which they were developed[14]. In this view, the object of persuasion is the scientific community, in charge of the validation of the theories presented. This validation is a process that, some authors argue, is not only scientific, but also social and even politic (Chalmers, A., 1991; Wenger et al., 2002; Sonnenwald, D. H. et al., 2004; Latour, B. and Woolgar, S., 1986; Vinck, D., 1995). Furthermore, once a fact has been established, modifying it seems too costly because it is considered reality. The scientific activity is then a "fierce fight to construct reality" through statements (Latour, B. and Woolgar, S., 1986). Consequently, the research organization is the place that allows this construction.

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[14] This issue is related to the theories citation behaviour in science. One of these theories is the normative theory of citation, in which "scientists cite to give credit where credit is due" (Moed, H. K., Garfield, E., 2004). In contrast, in the constructivist view, "scientists cite to advance their interests, defend their claims against attack, convince others, and gain a dominant position in their scientific community" (Moed, H. K., Garfield, E., 2004). This later view is coherent with the position of Latour, as it sees citation as a persuasion tool.

Additionally, there is a cyclic process because accepted statements[15] are reintroduced into research organizations in order to construct new facts reinforcing the statements. Therefore, challenging these statements results too costly and “reality is secreted” (Latour, B. and Woolgar, S., 1986).

This process aims at allowing scientists to continue to work on phenomena from the results obtained by his fellows. However, the passage from publications to the actual continuation of a research initiative is not straightforward. The reason is that an important amount of published papers remains often unread or misrepresented (Latour, B. and Woolgar, S., 1986). In fact, according to these authors, the fate (status, value, utility, facticity) of the texts generated in the process of constructing scientific facts “depends on their subsequent interpretation”[16]. Consequently, the role of publications as a way for sharing knowledge is not always achieved. However, there exist other means for conveying knowledge. We refer to artifacts that support the activity. In fact, we consider publications as a particular kind of artifact, used in science to convey knowledge.

- *The role of artifacts*

(Vinck, D., 1999) shows that the cooperation among scientists is partly structured by the exchange of physical entities. He calls these entities “intermediary objects” and defines them as “physical entities that connect human actors among them.” They may take the form of instruments, heavy equipments, reagents, phantoms, animals and even human beings (i.e. patients participating in biomedical research projects). These entities are “representatives of the concerns and the ways of working of the laboratory” and convey the know-how of scientists (Vinck, D., 1995). In this sense, the elements used by scientists would fit the meaning of the concept of *artifact* expressed by (Hutchins, E., 1999)[17]. For him, artifacts are

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[15] For (Kuhn, T. S., 1996) these accepted statements correspond to the shared paradigm on which scientists base their work in order to study a phenomenon.

[16] Poscript to second edition

[17] We note that we have chosen to use the concept of artifact rather than the one of intermediary object for two reasons: First, the concept of intermediary object focuses on the mediation among human actors, while our interest rests on the transmission of knowledge. Second, this concept has been largely used for describing interactions in design processes, which we thought could lead to misinterpretations about the meaning we

"repositories of knowledge… constructed in durable media". They can represent more than any individual can know. For (Giere, R. N., 2003)[18], artifacts (both physical and symbolic) are the reason why "we now know so much more than before". He claims "the cognitive process is distributed among humans and material artifacts." Therefore, artifacts allow us to become part "of distributed cognitive systems with overall cognitive capacities far greater than our natural individual capacities." This implies that it is necessary to take into account both, people and artifacts[19] when analyzing activities involving cognitive processes[20], such as the scientific activity.

Therefore, we could say that, in the scientific media, artifacts take two main forms: intermediary objects for experimentation and documents. The intermediary objects for experimentation can take the form of software or instrumentalities (equipment, instruments, etc.) developed for a research project or used for carrying out the scientific activities, together with the other elements used for carrying out experimentations (reagents, testing animals, etc.). These artifacts may take many forms depending on the domain of research and the context of the activity. Regarding the documents, their use is fundamental for all the domains (see section "The production of inscriptions"). However, the kinds of documents used may vary from one domain to the other. Nonetheless, a particular type of document is always present. This is the bibliography. We refer to the bibliographic documents used for acknowledging colleagues' works and for sharing one's own results, in all the scientific

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wanted to transmit. In this context (design), "intermediary objects are representations of a final, absent object… Their goal is to improve exchanges… the circulation of these objects becomes the place for constructing (dividing and integrating) collective action" (Vinck, D., et al., 1996).

[18] In the text, Giere uses the word "artefact" instead of "artifact".

[19] We note that this is coherent with the position of (Vinck, D., et al., 1996) regarding the role of intermediary objects in design processes. In this context, they say that the role of both intermediary objects and humans is equivalent. According to them, intermediary objects are "active" (resistant, creative or destructive). They are mediators (they do not convey the message identically), actors (they introduce some degree of freedom which cannot be reduced to the interplay of human actors) and translators (which implies interpretation) (Vinck, D., et al., 1996).

[20] A cognitive process is "the performance of some composite cognitive activity; an operation that affects mental contents; "the process of thinking"; "the cognitive operation of remembering"" (The Free Dictionary.com: http://www.thefreedictionary.com/cognitive%20process)

domains. Their omnipresence in the scientific activity together with the existence of shared channels of identification and diffusion of such documents (i.e. journals), not heavily dependant of specific local conditions as for other documents used in the activity (i.e. laboratory notebooks, formats, etc.), draw our attention towards them. We will now deepen into their use in the scientific activity.

1.2.3 The use of bibliographical documents in the scientific activity

Given the importance of bibliographical documents in the scientific activity, we will present the results of some studies done in different research organizations belonging to various research domains. These studies show the ways in which researchers and bibliographical documents interact when carrying out scientific activities.

In this sense, a first work we find useful is the one of (Meho, L. I., Tibbo, H. R., 2003). They analyze "David Ellis's information-seeking behaviour model of social scientists"[21], which "includes six generic features: starting, chaining, browsing, differentiating, monitoring, and extracting". The fieldwork they made verified Ellis's model and established four additional features. These new features are: accessing, networking, verifying, and information managing. All these features are organized into a new model in which they propose specifying four interrelated stages: searching, accessing, processing, and ending.

Given our own experience and observations of the interaction between researchers and bibliographical documents, we consider this model appropriate for approaching their study in order to facilitate the comprehension of the concrete aspects involved[22]. However, as the "human information behaviour" involves not only seeking, but also using information (Wilson, T.D., et al., 1999), we will slightly modify this model in order to explicitly take the use of information into account. We will use this modified model as a framework for

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[21] (Meho, L. I., Tibbo, H. R., 2003) note that Ellis's model presents "strong similarities with other influential models, such as that of Kuhlthau (1988, 1991, 1993), particularly in terms of the various types of activities or tasks carried out within the overall information-seeking process (Wilson, 1999). Ellis's model is also important because it was based on empirical research and has been used in many subsequent studies and with various groups of users (Bates, 1989; Choo, Detlor, & Turnbull, 1998, 2000; Ellis & Haugan, 1997; Sutton, 1994)."

[22] We note that we do not claim this model accurately reflects the practices of all scientists in all domains. Our objective is to use it as a basis for the study of these practices.

analyzing the interaction between researchers and bibliographical documents. Thus, we will analyze this interaction at three stages[23]: identification, processing and use of documents. Identification involves searching and accessing potentially relevant materials through formal and informal channels. Processing or interpretation involves synthesizing and analyzing the information gathered. The third stage is simply the use of documents for a project. We will delve into each one of these stages in the next sections.

1.2.3.1 The identification of bibliography

Some authors have verified the importance of the identification of possibly useful documents to the bibliographic research process. These works have been done with groups of scientists in different domains. Therefore, it is interesting to look at the conclusions of some authors who have done surveys for finding out how scientists seek and obtain the literature used in their work. The following are few of the authors we have found:

- (Davis, P. M., 2004) who studies chemists
- (Von Seggern and Jourdain, 1996) who study aerospace engineers and scientists
- (Brown, C. M., 1999) who studies astronomers, chemists, mathematicians, and physicists
- (Tenopir, C., et al., 2003) who study scientists using electronic journals
- (Jankowska, M. A., 2004) who studies university professors

These works give us some insights into the scientists' practices for identifying bibliography. Some authors verify the role of journal articles as a fundamental source of information in all work fields (Davis, P. M., 2004; Tenopir, C., et al., 2003; Brown, C. M., 1999), particularly peer-reviewed journal articles (Tenopir, C., et al., 2003). Moreover, the emergence of electronic journals (e-journals) (Tenopir, C., et al., 2003) and the integration of the journal literature with online indexing and abstracting services through linking services has transformed the search for information (Garfield, E., 2005). (Garfield, E., 2005) even predicts that "as full-text archives increase their chronological scope, you will be able to search and

[23] We note that we do not intend to provide an absolute model representing the practices of all researchers. Our aim is only to facilitate the analysis of such practices.

peruse the literature without ever entering the library."[24] (Tenopir, C., et al., 2003) has done a study that indicates a tendency in this sense by showing that the acquisition of journal articles is increasingly done through electronic library subscriptions. In addition, (Jankowska, M. A., 2004) verified the preference for electronic access to scientific and technical databases over print formats[25]. This electronic access is considered to be an enhancement factor of academic efficiency and capability, by allowing timesaving in searching, speeding up the research process and assisting students in their research (Jankowska, M. A., 2004).

Given the importance of journal articles, the choice of the journals is another key aspect. This choice seems to be particular to each research organization. Each one creates its own list of relevant e-journals, in spite of the existence of subject-based lists created by individual campus libraries (Davis, P. M., 2004). Furthermore, personal libraries are another important information source (Von Seggern and Jourdain, 1996; Brown, C. M., 1999). These are, sometimes, controlled trough software (such as EndNotes or BibTex) (Brown, C. M., 1999). Despite the interesting projects that have been and continue to be undertaken to facilitate access to documentary sources of certain scientific domains[26] there still is a specificity related to the literature used by each research organization and even by each researcher. If fact, it has been shown that obtaining journal articles is a personal task realized by scientists (Brown, C. M., 1999). The means for identifying the articles are browsing electronic journals, through other scientists and following citations (Tenopir, C., et al., 2003).

In addition to journal articles, another very important source of information is knowledgeable people (Von Seggern and Jourdain, 1996; Brown, C. M., 1999; Tenopir, C., et al., 2003). It has been particularly specified the importance of people nearby (within the same organisation) together with the material in the same building where each person works (Brown, C. M., 1999). Other information sources are the attendance to conferences (Brown,

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[24] (Garfield, E., 2005) also states: "Today we can access a significant part of the last decade of the literature electronically. In five to ten years, this will extend to much of the significant journal literature of the twentieth century, that is, the 1,000 or more most-consulted and higher impact journals. These journals account for over 80% of the literature cited."

[25] (Garfield, E., 2005) observes that « for some younger authors if it is not electronic, it does not exist."

[26] See for example : AstroWeb (http://cdsweb.u-strasbg.fr/astroweb.html), the arXiv.org e-Print archive (http://arxiv.org/) or Google's Library Project (http://print.google.com/googleprint/library.html)

C. M., 1999) and the Web, where the PDF format seems to correlate to the scientific nature of the publications (Jepsen, E.T., et al., 2004).

The results of the above surveys show the importance of journal articles, particularly in electronic format, as well as other sources of information, such as personal contacts. In addition, they show the importance of personal collections of articles, maintained by researchers as bases for their activities. The next stage is the processing of the identified documents. We present this subject in the next section.

1.2.3.2 The processing of bibliographic information

The processing of the information gathered involves its reading in order to assimilate its contents. The amount read by scientists varies. Scientists working in academia seem to read more than those in corporations or government laboratories (Tenopir, C., et al., 2003). Besides, a majority of scientists use electronic journals for at least part of their readings. In fact, the proportion of readings by scientists, from electronic sources, has increased (Tenopir, C., et al., 2003). Interestingly, although the majority of articles read are recent (no more than 1 year of publication), older articles tend to be considered more useful and valuable than recently published articles (Tenopir, C., et al., 2003). In general, it seems that the amount of reading per scientist, together with the time-spent reading, has increased. Additionally, researchers use electronic journals mainly for primary research, though current awareness is also cited.

Regarding the actual practices used for analysing the information, some works show the importance of annotations[27] (O'Hara K., et al., 1998; Marshall, C. C., Bernheim Brush, A. J., 2004; Peterson Bishop, A., 1999). However, the types of annotations distinguished differ. For example, (Marshall, C. C., Bernheim Brush, A. J., 2004), who studied a group of students using an online system for sharing their annotations, distinguish three main types of

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[27] (Sohn et al., 2003) write: "annotation in a document environment consists of text added for the purpose of explanation, description or emphasis on the subject of a document (Marshall, 1997, 1998b; Ovsiannikov et al., 1999). They are illustrated with style types such as underline, symbol, and note (Marshall, 1997; O'Hara and Sellen, 1997). Nowadays annotation technique is used widely in the electronic document environment (Roscheisen et al., 1995; Dymetman and Copperman, 1998)."

annotations: anchor[28] only, content only and compound (anchor and content). In contrast, (O'Hara K., et al., 1998), who studied the documentary activities carried out by doctoral students in the arts and humanities, differentiate four basic kinds of annotations, which correspond to the information recorded while reading documents: paraphrased content, verbatim information, readers' thoughts (bound to ideas in the text and knowledge in the readers' heads and ideas in response to a text), and bibliographic information (about the document read and potentially useful documents cited).

Though the works identify and classify different types of annotations, one can reasonably suppose that the technology change is at the origin of the different types distinguished. These technology changes may continue to alter the way scientist make annotations. For example, (Marshall, C. C., Bernheim Brush, A. J., 2004) remark the changes that tablet computers may imply in the reading and annotating practices of people, by possibly inciting them to read and annotate directly on the computer. They add "past studies have shown that personal annotation styles and practices translate fairly readily to tablet-based annotations" (Marshall, C. C., Bernheim Brush, A. J., 2004). Anyhow, what seems important is that some annotations only want to distinguish important paragraphs, others involve the reader's thoughts regarding specific passages, and others summarize aspects of a text.

For (Peterson Bishop, A., 1999), annotations constitute a way of disaggregating the document through the creation of surrogates (e.g. annotations, electronic entry with citation). These surrogates can serve for mapping out directions for enriching the literature review and for later re-use (O'Hara K., et al., 1998). However, they are not always public. (Marshall, C. C., Bernheim Brush, A. J., 2004) have shown that some annotations are meant only for personal use. This means that only a part of them, mainly compound annotations, is willingly shared with others.

These works show that scientists spend an increasing amount of their time reading and that the basic element for tracing the impressions had while reading is the annotations. However, more important than reading, is using the contents read for the benefit of the activity. For that

[28] According to the Wikipedia, "an anchor is the source and destination of a hyperlink" (http://en.wikipedia.org/wiki/Anchor_%28disambiguation%29).

reason, in the next section we will analyse the practices related to the applications of the documents read.

1.2.3.3 The use of bibliographic documents

According to (Yore, L. D., et al., 2002), bibliographic documents are used by scientists for improving their experimental design and for positioning their work within the current literature. This use is reflected in the writing of new documents, which is a collaborative process, where several people participate formally or informally (Cronin, B., 2004). Furthermore, the writing is cognitively distributed as social actors, scattered resources, tools, and artifacts take part in order to achieve the final text (Cronin, B., 2004). A part of the artifacts used corresponds to the surrogates created while reading, which, at the same time, disaggregates the documents (Peterson Bishop, A., 1999). This process seems to help scientists do the transition towards the writing of new documents (Peterson Bishop, A., 1999). In fact, annotations are used to re-acquaint researchers with the material, potentially bringing together information from disparate sources, which support the writing of new documents (O'Hara K., et al., 1998).

Some scientists specify "knowledge telling" as the main purpose of the new documents (Yore, L. D., et al., 2002). In these new documents "the reusable pieces crafted by researchers are re-aggregated: compiled and ordered somehow and eventually integrated into proposals, presentations and papers" (Peterson Bishop, A., 1999). These "reusable pieces" can correspond to already accepted text and citations of well-regarded scientists' work, which help to establish authority, common understanding, and creditability of the new documents (Yore, L. D., et al., 2002)[29]. The latter criteria might be the reason why some scientists generally read the same journals for which they regularly write (Yore, L. D., et al., 2002).

In conclusion, these works show the importance of bibliographic research for the writing of new documents. This kind of research serves multiple aspects: positioning the work, acknowledging colleagues' works and improving experimental design, among others. In addition, it may help as one of the bases for conferring confidence in the new documents

[29] See Section "The role of publications".

written. The latter is a process of re-aggregating pieces of information that may be collaboratively achieved by a group of researchers.

The writing of documents is the last aspect we consider fundamental for understanding the scientific activity, according to what the literature tells us about it. Another way of understanding this activity is by directly observing it. That is why we observed the activities performed at a research laboratory, as well as the practices of our laboratory colleagues. The main conclusions of this work are presented in the next section.

1.3 Our observations regarding the functioning of a research organization

In order to know the reality of research laboratories we did a fieldwork. In this sense, we agree with the position expressed by (Chalmers, A., 1991) who says that the methods and modes of progression of science "can and must be understood from the interior." The objective is to observe the concrete practices used in a laboratory. These practices affect the dynamics of the production of knowledge "as logic, nature, the scientific method or the society" do (Vinck, D., 1995). That is why we observed a research laboratory, during a four-month period.[30]

During this observation period, our position is similar to the one stated by (Latour, B. and Woolgar, S., 1986) who express the existence of a "degree of reflexivity" in their anthropological analysis of the scientific activity. In this respect, they explain: "By reflexivity we mean to refer to the realization that observers of scientific activity are engaged in methods which are essentially similar to those of the practitioners which they study." Thus, the outside observers' position is similar to scientists because "they are also confronted with the task of constructing an ordered account out of a disordered array of observations." This similarity can help observers better understand the scientific activity. In our case, one of the principles we

[30] For a detailed report of the results of this work the reader can consult the DEA thesis entitled *"Rationalisation des activités de recherche dans le cadre de la démarche qualité"* (Research Activities Rationalization in the Framework of Quality Management) presented on July 2002 (in French). The observations were done from March 2002 to June 2002.

were required to follow was to apply the same procedures used by other researchers for the development and follow up of the observation project. This allows a higher degree of understanding of the functioning of the laboratory, because we had to apply the very same procedures for the management of our project, although the studied phenomena deeply differed. We will now present the main aspects we observed.

1.3.1 Some characteristics of the functioning of a laboratory

The laboratory we observed works on the application of informatics to artistic creation. It was founded by three scientists. They work as senior researchers and are in charge of directing the three research fields of the organization: image, sound, and the development of an electromechanical platform for the generation of images and sound (real time division). Each research field has its own method of executing and documenting the activities.

The laboratory has three types of personnel: permanent personnel, students and the artists. The permanent personnel comprises only nine people who carry out different functions and are distributed in the following way: three founder members, a person for the administrative activities, three research engineers and two programmers. These personnel are distributed in the three research fields. The students are undergraduate and graduate students who participate in the research projects as part of their training. When we observed the laboratory, there were 20 students. Two of them were PhD students. The students usually stay for periods of about 3 years. The others were working on their master thesis or on engineering graduation projects. They usually perform internships lasting between 3 and 6 months. The artists go to the laboratory from time to time, to create artistic pieces with the aid of the developments of the laboratory. Figure 1 represents this structure.

While a part of the work of the laboratory is the development of software and hardware tools, its focus is basic research. Therefore, the observation of this basic research allowed us to verify certain aspects of it, which we now present.

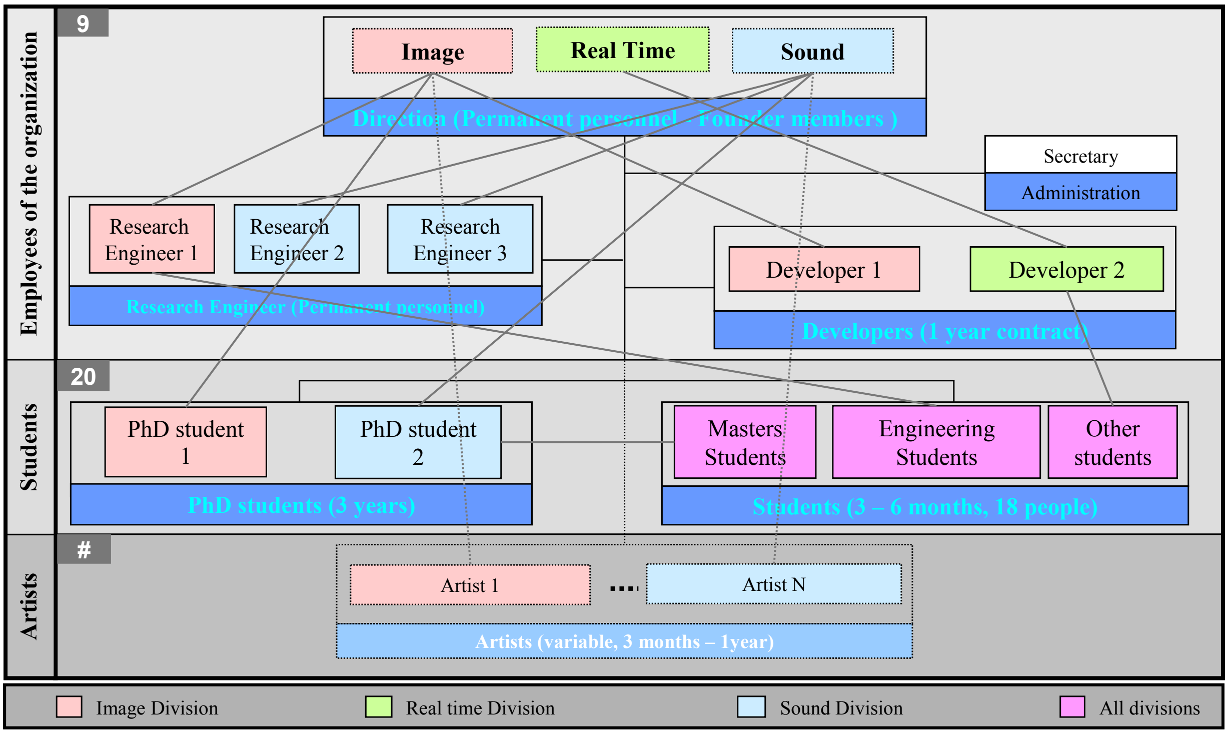

Figure 1. Structure of the observed organization.

1.3.1.1 The goal of the scientific activity

We verified that one of the fundamental characteristics of the research activity is that its goal can be defined as the augmentation of knowledge. The laboratory uses as a basis of its work a particular physics theory called CORDIS – ANIMA, which was conceived by one of the senior researchers of the organization. It is a theorem that makes a representation of the physics by using a discrete space (where the representations of the data are discrete). This representation is made thanks to the computer that is seen as a tool for simulation that functions with communicating processes (not with formulas, as in formal calculation). The objective of the activity is the enrichment of the Cordis-Anima theory through its modelling. This enrichment constitutes a cumulative work, which we will now explain.

1.3.1.2 The cumulative work

In each one of the three research fields in which the laboratory carries out its activities, there are several on-going projects at the same time. Some of them, mainly those assigned to engineering and masters students, are part of PhD projects, which in turn may be part of long-term projects undertaken by the laboratory. Each project must use as basis the Cordis-Anima theory and the results obtained by previous projects. This is reflected in the projects that contribute to the computational platform, where each project has to take into account previous developments. At the same time, these developments are seen as the evidence of the theoretical concepts generated by the researchers of the organization. Therefore, an important dimension of the work done is the collaborative aspect, we will now briefly consider.

1.3.1.3 The collaborative work

Students carry out a very important part of the work. The PhD students undertake part of the scientific aspects, while the engineering and masters students work on the technical aspects. The coordination of the students' works is the responsibility of the research engineers, who work in permanent contact with the students and serve as interfaces with senior researchers. The latter interact with the students on a less frequent basis. Additionally, there are projects where it is necessary that several divisions (two or even all three of them) work together. Thus, there is a diversity of activities that must be developed in parallel, with different deadlines, and which, often, must be coordinated to lead to valid results regarding the enrichment of the theory Cordis-Anima. In the case of projects involving all the fields, the coherence between the works carried out by each one of these divisions is not always achieved.

This is the way the laboratory organizes its activities. We will now explore the concrete aspects that allow the construction of scientific facts.

1.3.2 The construction of facts

As we mentioned, the basis of the work of the laboratory is the Cordis-Anima theory and the aim of the works done is to reinforce and complement this theory. This theory is the paradigm used by the organization. In the next section we will briefly explain this theory.

1.3.2.1 The acceptation of a paradigm

Cordis - Anima is a theory of physics, in terms of communicating and discrete processes. It requires the "re-writing" of knowledge in physics to be able to develop a modular system, which is different from the representation in physics (continuous). It makes possible the solution of the problems of physics in the computer. Cordis - Anima allows the digital simulation of audible, visible and easy-to-handle physical objects. It has been used at the laboratory since 1978 with the aim of proposing a new tool for artistic creation, based on the simulation of the object itself evolving in a virtual physical space. The objects created with Cordis - Anima have a physical characterization. They have physical parameters such as mass, stiffness, or viscosity, and they also adopt a behavior.

According to the directors, the distinguishing factor between the work done in the organization and computational work developed elsewhere is this theory. Therefore, given the special characteristics of this theory, one of the first tasks of the people arriving at the laboratory is to study it. The senior researchers say that, as formalism, this theory is not finished and has to be complemented. In order to do so, an understanding of the basic concepts is fundamental. In fact, it is one of the main problems of the senior researchers because these concepts are considered volatile and their respect, by all the actors who take part in the research process, is difficult to maintain.

The main pillar of the work of the organization is this theory, which is implemented through software and hardware developments. Another important aspect of the work is the realization of experiments, which we will briefly present in the next section.

1.3.2.2 The realization of experiments

The observations and experiments in the laboratory are usually done through computers coupled with different instruments. The instruments being developed at the laboratory are sometimes musical and sometimes electromechanical instruments. This depends on the objective of each project. The results of these experiments are documented according to the specific formats defined in each research field.

In general, the practices used for the follow-up of the projects are: regular meetings with other members of the project, presentation of reports to a higher qualified researcher, and presentation of the scholarly papers used for supporting the project. Different kinds of inscriptions result from these practices. They play a very important role for controlling the projects of the organization. For that reason, we will now analyze the role of the inscriptions in the organization.

- *The role of inscriptions*

The people working in this laboratory use and produce many documents. However, the documents produced present a high variability due to the freedom given to researchers for the documentation or the traceability of their activity. The consequence of this liberty was a marked differentiation among the contents recorded in the working papers. In consequence, experiences, reasons leading to decisions, explanations to procedures followed or to the algorithms developed are presented in different ways and with different levels of detail. This has had a negative effect on the development of activities, which becomes particularly evident when someone tries to continue someone else's work. In these situations, the difficulty to understand the previous work and the impossibility of contacting the person who undertook it, has even led in one case to the disposal of a whole algorithm and to the obligation to re-develop it in order to be able to advance the research. To avoid situations like this, the laboratory has established some measures, such as the definition of directives for the documentation of the algorithms developed or modified.

Given the importance the inscriptions have for the development of activities, the laboratory keeps written records of all the projects carried out since its creation. Paper records are preferred to digital ones because this avoids inconveniences due to the technological changes. These are part of the artifacts used and produced in the laboratory for the development of their activity. In the next section, we will explore how artifacts are present in the organization.

1.3.2.3 The role of artifacts

The laboratory undertakes different kinds of research activities in each one of its research fields. Therefore, the only type of artifact common to all projects is the document. The other artifacts involved vary. Thus, while some projects require computers and software for their development, other projects require electromechanical devices. Similarly, the artifacts produced also vary. Some projects involve musical creations, while others result in improved algorithms or in the design of special devises. Each research division manages the maintenance of the algorithms and of the devises it produces. In addition, for safeguarding musical creations, the laboratory uses tape records, as these assure the maintenance of the quality of the sound.

Two central repositories exist: one for the paper records and another one for the tape records. At the end of each year, an indexing work for the new material produced during the year is undertaken in order to add it to the repositories. This constitutes an important work for which additional personnel is hired. We note that when we made the observation there where already problems with the physical space these records demanded. In addition, retrieving a particular record required a permission, in order to maintain the organization of the repositories.

The observation we made was very useful for us. It constitutes the formal part of the observations we made. Informal observations complemented them. In fact, all along the development of the project that led to this dissertation we continued to observe the interactions and the activities as they are developed in our own laboratory. Together, both of these observations allow us to see the scientific activity as it is done on a daily basis. This let us see, concretely, how scientists produce knowledge. In the next section, we will present our observations regarding the use of bibliographical documents.

1.3.3 The use of bibliographical documents in the scientific activity

In general terms, we have verified the claims made by scholars regarding the use of bibliographical documents done by researchers. In our case, we observed engineering graduate students' practices working at our own laboratory, and made note of our own experience with bibliographic documents. Therefore, in the next sections we will complement the claims done by scholars regarding the identification, processing and use of documents in different contexts[31], with our own observations.

1.3.3.1 The identification of bibliography

We have verified the claims relating the identification of bibliographic documents. We have verified the importance of the PDF format for scientific documents, not only in Web publications, but also in conference proceedings and in scientific journals.

In addition, we have observed that the quantity of documents shared among researchers is not as important as it could possibly be among researchers working in the same subject. This is

[31] See section 1.2.3 The use of bibliographical documents in the scientific activity.

because, sharing documents is mostly occasionally done through informal conversations and not formally considered to be part of the activity.

An observation we have made regarding the identification of literature through personal contacts is that the credentials of the person recommending a document convey an implicit message about the degree of confidence in the content of the document and even about the credibility of its author. This is consistent with Vinck's position regarding the importance of the "confidence granted to individuals" for the evaluation of colleagues' works[32]. This aspect is particularly important for identifying older documents considered fundamental in a field, which can be especially useful for graduate students or for researchers who endeavour in the study of a phenomenon new to them. In this case, the identification is not only a matter of access to the sources of information (e.g. electronic sources or libraries), but also of the knowledge held by colleagues.

1.3.3.2 The processing of bibliographic information

Though we have observed the same processing practices identified in the literature, the concrete means to do it vary. Our observations have indicated the coexistence of paper notes with electronic files in order to organize the annotations. In addition, as personal preferences vary, so do personal practices. Therefore, some researchers prefer to read paper documents and take notes manually, while others rely as much as possible on electronic files and, many combine both formats. In addition, we remark that our own experience with the use of tablet computers has proven their utility for easily annotating documents without having to drastically change the practices used when annotating a paper document.

Another interesting aspect we have verified is that many of the annotations are intended only for personal use, reflecting the reader's own thoughts. As we see it, this can be consistent with the position of (Sveiby, K. E., 1996) regarding the fact that the tacit knowledge produced by the knowledge worker is not visible to others as the communicated part is only information.

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[32] (Vinck, D., 1995) writes: "Scientists say that it is often more efficient and more usual to evaluate colleagues' productions by taking into account their personality, their qualities, their reputation and their membership that by looking into the detail of their data, concepts and theories or by proving the shown results. The *confidence granted to individuals* plays a big role in the evaluation of works in science."

Paradoxically, that is why annotations sometimes are very useful for others. They give insights on the tacit knowledge held by its author. An example of this is the accidental sharing of annotations done by professors and their students when the former gives the latter photocopies of important articles or lends him a book. In this case, the marked passages show the aspects considered as important for the professor, which could be an indication of aspects to which the student should possibly pay attention. In addition, the notes may show his position regarding the claims done by the author. In this way, the interpretation of the document is not entirely left to the reader[33], as it contains aspects enriching the document that may provide important insights about it or about related aspects[34].

1.3.3.3 The use of bibliographic documents

Besides verifying the importance of bibliographic documents for supporting a research project, we have seen many difficulties in the use of bibliographic documents. These difficulties become flagrant when writing new documents. The problem is that documents and annotations are usually classified according to single criteria, while the writing of documents demands relating the claims of different authors on a specific subject. In practical terms this means that a single subject may be covered by different documents, but also one document can cover many subjects. Thus, relating scientific works on a subject demands a great effort from researchers.

Another difficulty comes from the lack of reutilisation of the previous work done in order to identify and interpret important works in a scientific domain. This means that after finishing a research project, only the final report is cautiously safeguarded, while the documents supporting it are discarded. Thus, the continuation of the work by other researchers demands starting the research of bibliography almost from the beginning. This also includes the undertaking of the practical aspects, such as getting hold of the documents before being able

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[33] According to (Sveiby, K. E., 1996) “Using Shannon's theory, information, is never 'facts', information is meaningless in itself and the meaning is constructed by the reader.”

[34] Related to the subject of annotations is the tradition of adding commentaries to ancient books. Regarding this subject, (Smith, B., 1991) analyses the role of commentaries in philosophy. He states that commentaries aim at making a given work “more easily accessible” and places the origins of the commentary culture in the Ancient Greece.

to analyse them. To counteract this situation, the laboratory we observed demands the submission of a copy of all the documents used during the realization of a project. However, as the filing is done in paper and only by projects, acknowledging their existence may result difficult for others.

1.4 Conclusions

In this chapter, we have shown what we consider to be the basic elements of science. The analysis of some theoretical claims allow us to define science as a process aimed at producing knowledge for better explaining the phenomena of the world. It is based on observation and on conceptual comparison. In addition, it is done in a cumulative and collaborative way, where knowledge is produced under societal and historical influences and is continuously updated by the scientific community.

Analyzing some of the characteristics of science, we established that what interests us is what (Kuhn, T. S., 1996) calls *normal science*, which refers to science as it is done on a daily basis at the laboratory. The result of this science is the production of facts, presented to the scientific community through formal communications that will, if validated by the community, lead to the adoption of the presented facts as part of the collection of accepted statements that constitute scientific knowledge.

The construction of these facts demands: accepting a *paradigm* (Kuhn, T. S., 1996), realizing experiments and exchanging information with colleagues. The acceptation of a paradigm involves the acknowledgement of previous theories, while the realization of experiments involves manipulating physical objects. However, all lead to the gathering and production of inscriptions that support the cognitive processes done by scientists in order to produce new knowledge. This new knowledge is represented by scientific concepts that aim at improving our understanding of a phenomenon. We have then an activity that manipulates artifacts and produces concepts[35].

[35] We note that we do not claim that the scientific activity deals only with these aspects. However, as our interest relies on the production of knowledge, at the interior of laboratories, other aspects linked to it (e.g. networking) are not taken into account.

For that reason, an important aspect of the activity is the use of bibliographic documents that support the acknowledgement of the works done in the research field, help improve the experimental design and present the scientific concepts already developed. These documents are used at three stages: identification, processing and use, which implies the application of the contents of the documents, as well as the production of new documents.

These theoretical claims were verified through the observation of a research laboratory. This observation also allowed us to gain a real understanding of the scientific activity. In addition, we observed some characteristics of the activity:

- The diversity of activity fields,
- The management of a great quantity of inscriptions and artifacts of different nature,
- The multiplicity of working methods, which lead to differences in the contents of the inscriptions,
- The regular turnover of personnel,
- The diversity of activities that must be developed in parallel, which, often, must be coordinated to lead to valid results

The laboratory has established some practices for dealing with these situations. They are of two types: Measures for managing inscriptions and measures for coordinating the work done by the people working in the different projects. These have shown to be useful, though some difficulties still persist.

In addition to the fieldwork we did at this laboratory, we observed our laboratory colleagues' practices related to the management of the bibliography. This, together with our own experience, not only allowed us to verify the theoretical claims regarding scientists' practices, but also helped us to understand the issues present in this activity. Among the most important observations are: the little reutilization of the work done within the framework of a project in relation to the bibliography and the utility of annotations, even when they are mostly unintentionally shared.

These observations encourage us to deepen our study of the activity in order to look for ways for better organizing it. For that reason, we explore the possibilities offered by quality management when applied to research activities. In order to do so, we observe the efforts done by a group of research laboratories to implement quality management. This permits us to know some of the problems they deal with and the ways in which they try to solve them. The observation of the approach used, the aspects taken into account, as well as those not explicitly involved in the implementation of the quality management system, are used to see the possible relation between the quality management system, as it is implemented in the laboratories observed, and the production of scientific knowledge. The objective is to determine if the implementation being made helps in the improvement of the structuring of the knowledge production process. In the next chapter we present this subject.

Chapter 2. Quality Management in Research Organizations

"There are no direct means whereby anyone outside the world of science can exercise quality control on science. The products of the craft work of scientists are intelligible, and valuable, only to other scientists. And although they relate to the external world, their value as well as their meaning is governed by the judgments of men, those particular men who enjoy this esoteric activity. If the government of this work were accomplished through formal institutions, then its response to changing conditions would be delayed, and the work might have time to adapt itself gradually while maintaining its excellence. But the nature of the work requires a government for direction and quality control which is almost entirely informal, accomplished be a series of craft skills which become ever more refined, demanding and delicate; and the work itself is very sensitive to the quality of its government. The problem of quality control in science is thus at the centre of the social problems of the industrialized science of the present period. It is fails to resolve this problem, and does not develop new techniques for restricting prestige and rewards to those who deserve them, then the immediate consequences for morale and recruitment will be serious; and those for the survival of science itself, grave." (Ravetz, J. 1971)

2.1 Introduction

We have seen that the objective of science is to produce knowledge (Chalmers, A., 1991). According to some scholars, it is an activity that increases *"the stock of useful knowledge"* (Salter, A.J. and Martin, B.R., 2001) available to society, which could be used for innovation and in this way contribute to economic growth.

The good management of these organizations is then an important issue. Consequently, some organizations, such as the AFNOR (French Standardization Association), the American Society for Quality (ASQ), the NEN (Netherlands Standardization Institute) and the U. S. Department of Energy (DOE) have established guidelines for the implementation of Quality Management Systems in Research Organizations. However, the introduction of quality management into the scientific environment is not currently backed by a well defined methodology. In fact, quality management has traditionally been used by industry. However, the general characteristics of scientific activity are different from those of industrial activity in terms of working conditions, goals, resources, tasks performed, etc (Ravetz, J., 1971). Thus, the introduction of quality management requires a methodology adapted to the scientific environment.

In spite of this, during the last few years, some research organizations have invested a part of their efforts into quality management as a way of dealing with the multiple concerns of their activity. Therefore, we observe a situation where, while some groups claim that quality management can be used by the scientific actors, some research organizations are indeed implementing quality systems within their organizations. For this reason, we have started a research process that aims at knowing the methods used by research organizations when implementing quality management systems, and the role this system can play in the transmission of knowledge. In particular, our objective is to verify the hypothesis according to which quality management can be used to support the knowledge production process by providing researchers some tools (which could be methodological ones) to assist their activity.

In the first part of this chapter, we present the main quality concepts for the research context. In the second part, we will show our observations about a few research units trying to implement quality management systems. Finally, we present our conclusions regarding quality management in research.

2.2 The Quality Principles

Quality concepts appeared many years ago in the industrial environment as a way of guarantying conformity of the produced goods (De Medeiros, D. D., 1998). Their applications and evolution continued in this context (De Medeiros, D. D., 1998, Mathur-De Vré, R. 2000). However, in the year 2001, the AFNOR published a document claiming that Quality Management could respond to many issues of the scientific activity (AFNOR, 2001). As the industrial and scientific environments present differentiating characteristics, fundamental quality concepts take a special meaning. In this section, we will explore the meaning of some of these concepts.

2.2.1 What is Quality?

One of the most widely accepted documents regarding quality management is the ISO 9000:2000. This document defines quality as the "degree to which a set of inherent characteristics fulfils requirements" (AFNOR, 2000a). However, in basic research activities, requirements of the products are not always well defined, and even the final products may not be known at the beginning of a research project. In fact, when talking about quality in the research context, the concept applies to the process and not to the product, whose "quality" will be judged, at first, by using methods such as the "peer-review" system. In fact, the scientific practice already involves mechanisms for verifying the quality of the research products. Furthermore, scientists strive to maintain the quality of research. Therefore, we talk about quality IN research and not about quality OF research. (Biré et al., 2004) say "in quality in research the emphasis is put solely on the conduct of the research." Consequently, the requirements refer to the activities developed as part of this process. (Mathur-De-Vré, R. 2000) says: "quality implies a level of goodness or excellence that provides satisfaction." For searching this level, a Quality Management System is usually implemented.

2.2.2 The Quality Management System

The ISO 9000:2000 defines the Quality Management (QM) as the "coordinated activities to direct and control an organization with regard to quality" (AFNOR, 2000a). Then, the Quality Management System (QMS) is defined as a "management system to direct and control an organization with regard to quality" (AFNOR, 2000a). At the same time, the management system is defined as a "system to establish policy and objectives and to achieve those objectives". Another definition is provided by (Mathur-De-Vré, R. 1997), who says, "A Quality Management (QM) System means the general organization of a laboratory in terms of quality requirements to assure proper management and organization." In contrast, the (AFNOR, 2001), when talking about quality in research, says that quality "can offer a coherence framework allowing each one to think about his "professional ways of doing" in order to improve them on a continuous way." For that reason, we propose the following definition of a QMS in the research context:

> *The system in charge of the establishment of coordination mechanisms a research organization will use to define and manage the activities aimed at*

> *improving the realization of the actions carried out in order to achieve the objectives of the organization.*

Consequently, applying this concept to the research context demands the definition of the specific aspects that should be included in the system, as well as the concrete activities leading to a successful implementation. For that reason, some institutions around the world have established some directives indicating the implementation of this practice into scientific environments. Examples include the U.S. Department of Energy which, in 1991, established that the basic and applied research facilities sponsored by the Office of Energy Research *"shall develop, implement, and maintain a written Quality Assurance Program"* (U.S. Department of Energy, 1991), NASA which, in 1996, decided *"to be leaders in the world of quality"* (Kasvi, J.J.J. et al., 2003), and the AFNOR which, in 2001, published a documentation booklet (AFNOR, 2001) that proposes the application of quality management to the research process. These statements have been accompanied by some quality standards (QS) proposing guidelines for the implementation of QMS. In the next section we present some of the quality standards intended to guide these processes in research organizations.

2.2.3 The quality standards for research organizations

The Quality Standards (QS) intended to guide the implementation of QMS in research organizations involve the standards intended for testing laboratories. These present two figures: Those intended for accreditation and certification purposes and those that present guidelines for improving the QMS at a research organization without aiming at the certification of the system. We will briefly present them hereafter.

2.2.3.1 QS for Accreditation and Certification

According to (Mathur-De-Vré, R. 1997), there are three QS that could be possibly used for the accreditation and certification of a research organization:

- ISO 9001 (AFNOR, 2000a): the ISO 9001 is a general standard conceived for organizations of all types and not only for research organizations. In fact, its application has been mostly done in the industry.

- EN 45001[36]: This standard is not particularly envisioned for research laboratories. It specifies criteria for the evaluation of testing and calibration laboratories for accreditation (technical competence and general quality management system). This standard has been replaced by the "ISO/IEC 17025 'General requirements for the competence of calibration and testing laboratories' is a standard setting out the criteria for a quality management system for a laboratory."[37] This "standard applies to test (including research and development laboratories) and calibration laboratories". According to (Biré et al., 2004) some of the requirements included in this standard are "either incomplete or too restrictive to apply, in that state, to research activities." For that reason, it has been applied to routine analyses.
- The Principles of Good Laboratory Practice (GLP), (OECD, 1998): This standard is not particularly envisioned for research laboratories either. The GLP "have been developed to promote the quality and validity of test data used for determining the safety of chemicals and chemicals products" (OECD, 1998).

As we can see, among the quality standards for accreditation and certification, there is not a document focusing particularly on quality management in research organizations. We will now explore other existing documents that provide guidelines for implementing quality in research without aiming at the certification of the QMS.

2.2.3.2 QS Non-Intended for Accreditation Purposes and other Guidelines

There are other documents that present specific guidelines for introducing quality in research. These are:

- US Department of Energy – 1992. D9E-ER-STD--6001 -92 / DE92 016352. DOE Standard - Implementation Guide for Quality Assurance Programs for Basic and Applied Research. According to the (U.S. Department of Energy, 1992), "this Implementation Guide is intended to assist management at DOE-ER sponsored facilities in the process of developing and implementing Quality Assurance Programs". However, the document states that "DOE 5700.6C section 4 e. states that the "work results which undergo peer

[36] EN 45001 (1989) General criteria for the operation of testing laboratories. CEN/CENELEC

[37] http://eulab.nen.nl/frameset.htm?url=%2Fcontent%2Fenglish%2Fkwaliteit_normen_en.htm

review for publication are exempt from the scope of DOE 5700.6C."" which is usual in fundamental research.

- Netherlands Standard - 1992. Quality assurance. Additional requirements to NEN-EN 45001 for research laboratories. NEN 3417[38]. According to EU-Lab[39], "For the research laboratories in the Netherlands, in addition to NEN-EN-ISO/IEC 17025, there is also the NEN 3417 'Kwaliteitsborging - Aanvullende eisen op NEN-EN 45001 voor onderzoekslaboratoria' (Quality Assurance - Additional requirements to NEN-EN 45001 for research laboratories) as a supplement to NEN-EN 45001. NEN-EN 45001 is one of the predecessors of ISO/IEC 17025 published in 2000. NEN 3417 deals with a number of aspects for research laboratories not found in ISO/IEC 17025. These aspects do not however conflict with what is laid down in ISO/IEC 17025." According to the Quality Plan 2002 of the French Research Ministry (Ministère de la Recherche, 2002), this is a constraining standard intended for the test laboratories, which has not been translated into English (only the draft was translated in 1992).
- American National Standard - 1999. Quality Guidelines for research. ANSI/ASQ Z1.13-1999. "This document can be used in the development of a quality system for basic and applied research. This includes fields like the biological, physical, and applied sciences use methods such as field investigation, laboratory experimentation, computer modeling, and theory formulation."[40]
- The European Association of Research and Technology Organisations (EARTO) – 2000. General Guidelines for the Operation of Research and Technology Organisations. According to (EARTO, 2000), "this document establishes the general guidelines a research and technology organisation (RTO) should follow in its practical work. It covers all types of research using methodologies that have been published, methodologies that an RTO uses and methodologies that it has to develop." According to (Biré et al., 2004) they incorporate the requirements of ISO 17025 and requirements specific to research activities run as projects.

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[38] NEN-3417 (1992) Complementary requirements of the norm NEN-EN 45001 for research laboratories. Netherlands Standardization Institute, The Hague.

[39] http://eulab.nen.nl/frameset.htm?url=%2Fcontent%2Fenglish%2Fkwaliteit_normen_en.htm

[40] http://e-standards.asq.org/perl/catalog.cgi?item=T740E

- The French Guidelines – 2001. FD X 50-550 (2001) Quality Management in Research - General Principles and Recommendations. French Association of Standardization (AFNOR, 2001). This document aims at "formulating recommendations for the implementation of a coherent QMS in the research activities as well as within the functioning of the institutions where they are carried out." This document claims to be the first work of this kind at an international level. It marks a very important step forward in quality management in research, given its official nature and its broad application spectrum. It has been complemented with two additional documents:
    - FD X 50 – 551 (2003) Recommendations for the organisation in mode project of a research activity managed and carried out within the framework of a network. This document aims at guiding the identification of aspects presenting risks within the realization of a project and does not requires a QMS formally implemented in the organization (AFNOR, 2003).
    - FD X 50 – 552 (2004) ISO 9001 Application Guide for a Research Organization. This document aims at facilitating the appropriation of the ISO 9001 standard by research organizations. For this purpose, it explains the meaning of the quality notions in the research context. It provides examples showing the way in which these notions have been used by some research organizations having already implemented and certified their QMS (AFNOR, 2004). Though this document is intended for "all the research organisms, both public and private" some aspects show that it is mostly focuses towards applied research. This can be seen through the examples provided, which present mostly well-defined processes, where indicators can be clearly specified or where the scope defined limits the application to the departments providing services (such as testing) to research projects. This is not to say that the document is not useful, but that it will be surely necessary doing an important interpretation work of this document in the framework of each particular case.
- International Standardization Organisation - ISO 10006:2003. Quality-management systems—guidelines for quality management in projects. This standard provides some

guidance on the application of quality management in projects[41]. Nevertheless, according to (Biré et al., 2004), it does not "incorporate notions of prime importance to research activities".

These standards are primarily focused on three kinds of problematic: Laboratory Tests, Project Management and Quality Management itself. In these, recommendations are done regarding documentation, management, equipment and other aspects aimed at ensuring the realization of laboratory activities, organizing the realization of the activity in form of projects and improving the structuring of the whole organization. For that reason, we present hereafter the role quality management seems to play for research organizations.

2.2.4 The Role of Quality Management

A central preoccupation of some of the above mentioned standards seems to be demonstrating credibility of the results. According to (Biré et al., 2004) in research, the total quality management concept means "proving the reliability and credibility of the research results is to demonstrate that critical points in terms of quality requirements are controlled throughout the whole research process, from the very beginning until the end." Additionally, (Mathur de Vré, R., 1997) says that "a formal QA [quality assurance] system in R&D promotes mutual confidence among all parties concerned." In addition, the (AFNOR, 2001) says that the parties involved in research request to have confidence in the scientific knowledge produced as well as in the scientists' practices and research entities. If this is the case, this could imply two things: First, the peer review process does not sufficiently assures the scientific knowledge produced (as it is not enough for demonstrating credibility) (Ravetz, J., 1971). Second, QMS should be certified, in order to demonstrate its existence and correct implementation. However, as we have seen, there exist several documents providing guidelines for the implementation of QMS that are not intended for certification purposes. For that reason, we were interested in the concerns and in the actual practices implemented by research laboratories when they engage in the formal implementation of a QMS. The formal character is taken here as the definition of a team responsible for the implementation, who establish written documents defining the "ways of doing" (AFNOR, 2001) the activities of the

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[41] http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=36643

organization and establishes measures to improve them. Thus, in order to study the formal implementation of QMS, we made a field work in order to see some real experiences of this kind. We present our main conclusions in the next section.

2.3 Some Experiences of Implementation of QMS in Research Organizations

In order to gather information about the real practices and concerns of research laboratories when implementing QMS we have performed a field work, using a sociological approach for accomplishing it. This work has three main phases:

- Observation: This phase consisted on the observation of a research laboratory, the ACROE – ICA, where efforts for improving the development of the activity are carried out, but without following any of the existing QS[42].
- Interviews: In this phase, eight interviews with the people responsible for quality management at seven research organizations where formal efforts of introduction of QMS were carried out. These interviews account for approximately 16 hours of voice recordings. These interviews were done in two stages: The first one, at the beginning of the year 2002, when two laboratories were interviewed. The second one, during the first semester of the year 2003, when 5 additional laboratories were interviewed.[43] It is important to note that the formal character of the initiatives going on in these laboratories is shown through the establishment of a specific quality management project, with a well-defined working group, a budget allocated for the development of the activities and the support of an external consultant to guide the activities of the project. These projects, with one exception, have all been started voluntarily.

[42] Part of this work led to the conclusions presented about the functioning of scientific institutions (See Chapter 1. Science, section 1.3.1 Some characteristics of the functioning of a laboratory)

[43] The information about the laboratories were the interviews were realized, together with the complete summary of the results of these interviews can be seen in the Research Report 170603a (in French).

- Follow-up study: This consists of the follow-up of the implementation process of the quality system at a research laboratory during 18 months[44]. This work has been done at the Astrophysics Laboratory of the Sciences of the Universe Observatory of Grenoble (France)[45], which is one of the seven organizations where the interviews were carried out. This work corresponds to the participation, as observer, at eight meetings (of approx. 3 hours each) of the piloting committee responsible for the implementation of the quality management system. This committee is headed by a senior researcher. In it, representatives of the realization of the organizational aspects of the laboratory also participate. Concretely: The person in charge of the administration and the one in charge of the computing support. Additionally, some researchers, who have additional responsibilities in charge, also participate. These researchers are: the one in charge of communications, the one in charge of the technical support, the one in charge of Safety and Hygiene, and the one responsible for training of students. There are also other persons that participate depending on the subject of the meeting. Among them the director of the laboratory, who only participates when a general balance of the project is done. In addition, we participated at four sessions of the working groups in charge of the realization of the activities defined by the committee: One session of the working group in charge of the development of the procedure for the integration of newcomers, another one of the working group on administration (that works on purchasing, displacements, and internal regulations), a session of the working group on the management of instrumental projects and one session of the working group on quality in research activities. The latter was the one in which we were more interested. It did not pursue its activities because the committee considered the project demanded already an important load of work and decided to wait until the other actions were already implemented. However, this meeting was held on July 4th, 2003 and after that date no new meeting has been done. Regarding the meetings of the committee, the last meeting was held on June 28, 2004. According to the person responsible for the project, other activities have taken over the priority and have prevented the realization of new meetings. For that reason, we have not been able to

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[44] This work started on February 4th, 2003 and was continued all along there were meetings being held. The last meeting was held on June 28th, 2004. After that date, no new meetings have been organized.

[45] For information about this laboratory see: http://www-laog.obs.ujf-grenoble.fr/

pursue the observation of the implementation of the QMS at this laboratory. Nevertheless, we have recently started following (March, 2005) the implementation process at another laboratory, the Centre de Recherches sur les Macromolécules Végétales – CERMAV [46] (Research centre on the Vegetable Macromolecules) that had been interviewed in March 2003 and has recently started working towards the introduction of QM in the PhD projects.

These works have showed us some interesting aspects regarding the approaches used when implementing a QMS. In this section, we present some of these aspects.

2.3.1 The Motivations to Work on Quality Management

The observation phase showed that the main concern of the directors of the ACROE – ICA was the coherence of research results. It is important to remind that the research projects carried out in this laboratory are based on the works done by those who are its initial founders and current directors. Therefore, the coherence of the research results with the basic initial concepts is considered fundamental to ensure robustness in the evolution of the work. Consequently, the practices established have three main objectives:

1. The maintenance of respect for the basic theoretical principles.
2. The maintenance of coherence between the activities.
3. The facilitation of project development.

According to one of the directors, the volatility of concepts, of "knowledge" necessitates the implementation of the means to maintain them, which means guaranteeing their conformity to the original meaning and their transmissibility. Therefore, in this organization an essential aspect regarding the implementation of quality management is the respect for concepts. The problems are mainly related to the maintenance of the knowledge concerning the scientific concepts that support the activity, because its respect, by all the actors who take part in the research process, is difficult to attain given the characteristics of the research organization.

Nevertheless, there is a divergence between this vision of the management, and the perception of the personnel. In fact, the personnel express a lack of structure in the activity, which is reflected in very practical situations that affect the daily activity. The management has

[46] For information about this laboratory see: http://www.cermav.cnrs.fr/une_gb.htm.

acknowledged this situation and has concluded that the absence of external directives leads to a situation where *"the first customer of the organization is the team itself"*. It is thus necessary to implement a system that respects the management's vision and that, at the same time, satisfies the staff needs.

This situation is also noticed in the interviews phase. All of the interviewed organizations, with one exception, started working on quality management because of internal needs. Most of them perceived the need for improvement and found in quality management concepts a possible answer to their concerns. Hence, the motivation comes from the inside and not from the outside of the organization.

This observation is important mainly for two reasons: First, the concern stated by the QS about the confidence of research actors in research results was not verified by the cases we observed. If the motivation of these organizations was confidence, that would mean implementing actions to respond to a need for validation of research results. However, scientific practices already include validation methodologies and therefore, quality management is seen rather as a means to structure the activities of the organization. Confidence or credibility has to be firstly gained at the interior of the organization as a result of the process. Consequently, and here we arrive at the second reason, the implementation of the system should focus on the need for ensuring robustness, answering manager's needs, structuring activities to facilitate their completion and, in this way, respond to the needs of the personnel. In this sense, QMS seems to aim the better development of the activities of the organization, in order to respond to the requirements imposed by the same collaborators working in the organization. This does not mean that the credibility of the results is a subject of less importance than the aspects mentioned above, but that for the observed cases, this was not the motivation.[47]

We have established why research organizations work on quality management. We will now look at the model these organizations use for implementing quality management.

[47] It is important to remind that the projects we observed were started voluntarily. Then, it is not surprising that the motivation behind the project be internal rather that external.

2.3.2 The Model Followed for the Introduction of Quality Management

To enhance our understanding of the problems seen and to have sufficient elements for analysis, we carried out eight interviews in seven research organizations[48], located in Grenoble (France) and attached to the CNRS (National Centre of Scientific Research of France). They are all important research laboratories, with the exception of a service that works for the research laboratories as a supplier of special equipment for research projects. These organizations were all working on the implementation of their QMS under the guidance of one same consultant. This consultant also participates in our project and helped us with the identification of the laboratories working on QM, which facilitated us the contact with the person to interview. The interviews were done to the person(s) in charge of the implementation of the QMS. This involves four researchers, three research engineers and two technicians[49]. These interviews account for approximately 16 hours of voice recordings. These recordings were comprehensively transcribed. They were then analyzed in order to define the possible existing trends in the implementation processes. The conclusions of this analysis are presented hereafter.

Most of the interviewed organizations have been engaged in quality management since the year 2001. In addition, the QMS are inspired by the principles of the standard ISO 9001 (AFNOR, 2000) and have resulted in the establishment of information systems that aim to facilitate the completion of repetitive processes. In addition, the basic difference between the quality systems is related to the type of activity carried out: two of the organizations work in applied research (or the quality system is used only for this activity) while the others work mainly on basic research. This results in divergent ways of establishing the systems: the first group, those that work on applied research, followed a traditional process for the establishment of a quality system according to the standard ISO 9001 (AFNOR, 2000), while the second group, those that work on basic research, has been forced to carry out an analysis on the way the directives of this standard could be applied to research in order to adapt them to their own mode of operating. This situation suggests differences in the methodologies that should be used according to the activities relevant to the quality management system.

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[48] See Research Report 170603a (in French).

[49] There were two persons interviewed in two of the laboratories.

In the next section we explore how the implementation has been done in the different laboratories.

2.3.3 The Aspects Included in the Implementation

The observations we made lead us to recognize the presence of three kinds of activities within research organizations: Scientific activities (basic and applied research), which are responsible for the production of knowledge; support activities, which allow the development of scientific activities and Managerial activities, which are responsible for the coordination and orientation of the activities. This is coherent with the "ISO 9001 Application Guide for a Research Organization" (AFNOR, 2004) that states the existence of three types of processes[50]. Accordingly, the development of the project demands the participation of personnel belonging to these three processes:

- Direction of the laboratory: The director of the laboratory is usually represented by a senior researcher. The active participation of the director on the project is considered an important factor as allows decisions to be taken and shows the importance of the project. However, this active participation is not always attained.
- Support Functions: The personnel working in the support functions follow a functional logic such as: Informatics, Finances, and Administration. In the follow-up study, we have observed that they have a very active participation in the project.
- Scientific personnel: They work on a scientific project-logic based on knowledge domains. The participation of scientists is usually rather limited. Though the projects have been generally started with the participation of a few scientists interested in the improvement of the activities, the involvement of other scientists has been difficult to attain. In addition, the work on the QMS is voluntary and, therefore, additional to the scientific responsibilities. For that reason, it usually lacks priority over the other activities.

This means that if we take into account the characteristics that (Huang, J. C. and Newell, S., 2003) specify for cross-functional projects, we could say that the implementation of a QMS

[50] It is important to remind that one of the main principles on which the ISO 9001 is based is the process approach. This principle says: "A desired result is achieved more efficiently when activities and related resources are managed as a process." (ISO, 2000)

demands a cross-functional logic[51]. In these projects people working under a functional logic and people working on a science-project-logic are obliged to work together, to communicate and therefore establish a common language, build shared practices and share beliefs (such us what has a high priority and what does not)[52]. In particular, in the development of common practices required for carrying out the activities involved in the implementation of the QMS, the project team learns the necessary methods for achieving it (which are partly taught by the consultant participating in the implementation).

During the implementation, the people working in diverse activities participate in order to analyze the processes of the organization and try to establish mechanisms to improve the way in which they are done. As the implementation is done with the participation of people from the different divisions of the organization, it is possible to think about the existing worries at different levels in order to establish priorities in the processes to be analyzed. This allows analyzing each process throughout all the stages performed by the people who participate in a process. Thus, the constraints, logic, advantages and disadvantages of the practices in place are analyzed and taken into account for the definition or the re-definition of the processes of the organization. This is usually done through a formalization of the activities materialized partly as documents (procedures, operational documents, formats, etc.) showing the way in which the parties involved in the definition of the procedure agreed on performing a process.

In the cases we have observed, and particularly in the follow-up study, the implementation of quality management has started by the support activities, where the quality concepts and methods are applied with less difficulty by using a methodology based on two elements:

[51] According to (Huang, J. C., Newell, S., 2003), "cross-functional project teams enable an organization to pool together a wide range of expertise from various units to accomplish complex tasks which cannot easily be dealt with by one unit."

[52] We note that some aspects are more the result of an agreement than of a shared belief. For example, the definition of the tasks to be done regarding the informatics support are the result of a negotiation where the load of work of the person who would have to perform these tasks and the needs of the other divisions of the laboratory are taken into account and discussed in order to define the tasks to be done and the terms in which they will be done (See CommitePilotage-200203).

- The formalization of activities through the definition of procedures and other support documents, that specify the way in which these activities should be carried out.
- The definition of standardized practices for the management of the related documents.

In this way, it may act on all the organization, because the formalized procedures may incorporate modifications to the practices in place. Conversely, in some cases, the process as a whole is not analyzed, but rather the analysis and formalization is done for some specific aspects considered as a priority (e.g. development of data banks rather than the whole research process).

The introduction of quality practices to support activities allows the personnel to get familiar with the quality concepts and methods. At the very beginning of the implementation process, these concepts and methods are considered to be completely abstract and difficult to internalize, as they do not belong to the traditional practices used by research organizations.

Regarding the implementation of quality management in scientific activities, it has been observed that some of the organizations have been able to implement it for technical activities and for some specific aspects related to the scientific activity. Among these aspects we find the management of experimental data (in two laboratories), the management of the documents related to the projects (planning, minutes and reports)[53], the management of publications (in two laboratories) and recently (beginning of the year 2005), a laboratory has started working towards the improvement of the management of PhD projects. In spite of these examples, the implementation in research is, in general, considered harder and, therefore, envisioned to be undertaken only at a later stage, when practices have somewhat stabilized in support activities[54]. There seems to be two reasons for this situation:

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[53] This activity was implemented only at one of the research teams of one of the interviewed laboratories.

[54] At the moment of the interviews, only one of the laboratories had included the research activities within the scope of the QMS being implemented (for the management of the documents of research projects). Another laboratory had started working towards the analysis of the way in which quality management could be used for managing the scientific data. Regarding the others, they expressed their interest in starting to reflect about this subject, focalising particularly on how quality management could be applied to PhD projects. Of these, only one of them has recently (beginning of the year 2005) started working in this subject. Additionally, the GREQ - *Groupe de Réflexions et d'Echanges en Qualité* (Think tank about Quality) has recently (July, 2004) started a

- Firstly, a defined methodology to apply quality management to scientific activities does not exist. A document that could help establishing this methodology is the FD X 50-552 - ISO 9001 Application Guide for Research Organizations (AFNOR, 2004). However, this document has just been published and it also needs to be interpreted in order to use it. Additionally, the application of the guidelines provided to some of the basic research situations is not obvious and still demands a deep analysis of the concrete situations faced by each research organization.
- Secondly, the results obtained by applying quality management to organizational aspects are easily perceived in the short term by the personnel, which is hardly the case for research activities.

In addition, there are particular situations that may affect the implementation of QM in research activities. According to one of the people we interviewed, "researchers are persuaded they do quality permanently... when one talks to them about quality, they feel attacked"[55]. In fact, there are already practices aimed at maintaining the confidence in the results obtained (for example, the keeping of laboratory notebooks, the realization of several experimentations to test the results, etc.). Thus, the laboratories undertake their research activities by following the practices traditionally used in research[56]. However, to implement a quality system in the research activity directly affects the central activity of the organization and may demand modifying some of the current practices used for developing the activity. The question is if it is possible to define ways for improving the support of some aspects of the research activity in order to facilitate the activity of researchers.

In addition, it should not be forgotten that the phenomenon of quality in research is rather recent. It is thus understandable that the systems initially address the aspects perceived as accessible. Additionally, we observe that the lack of documented case studies of the

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network for the exchange of experiences on the subject: Quality in Research in PhD and Post-doctoral projects, which counts with the support of the Research Ministry of France and aims at proposing actions plans to be implemented in research laboratories.

[55] See Research Report 170603a (in French).

[56] We refer mainly to the freedom given to research teams and to project leaders to decide on the procedures used for the realization of research activity.

implementation of quality management in basic research activities is a factor that affects enthusiasm for such a process.

2.4 Conclusions

In this chapter we have presented some basic concepts about quality management in research organizations. We showed that in this context the objective is supporting the processes of the organization and not, at least not directly, address the quality of the research products. Therefore, we talk about quality IN research and not about quality OF research.

In addition, we illustrated the documents providing guidelines for the implementation of QMS in research organizations. These documents are primarily focused on three kinds of problematic: Laboratory Tests, Project Management and Quality Management itself. Though there exist a number of documents and standards for laboratories, the field work we have done, lead us to observe situations where the model mostly used for the implementation of the QMS is the ISO 9001:2000.

Another important aspect is that, according to the standards and guidelines for quality in research, a central preoccupation should be demonstrating credibility of the results in order to gain the confidence of the research players. However, the fundamental problems of the research organizations we studied are neither the confidence of the research players nor the reliability of the knowledge produced, but the improvement of activities carried out. The follow-up study we have done at a research laboratory implementing a QMS shows that the implementation follows this approach. In addition, given the difficulty of the personnel for comprehending quality concepts, the systems have started by addressing the support activities and very little the research activities, that have only been object of consideration and active work at some laboratories (manly two laboratories, and partially at a third one). Nevertheless, even in these cases, the QMS have only covered specific aspects of the research activities, with a particular focus on the improvement of the management of the scientific data. The other basic research aspect we could observe is the management of the publications (for major publications). In this sense, the QMS address aspects that support the central function of the organization, which is the production of knowledge, but not the activities directly in charge of carrying it out. Figure 2 schematizes the implementation of QMS in the observed research organizations.

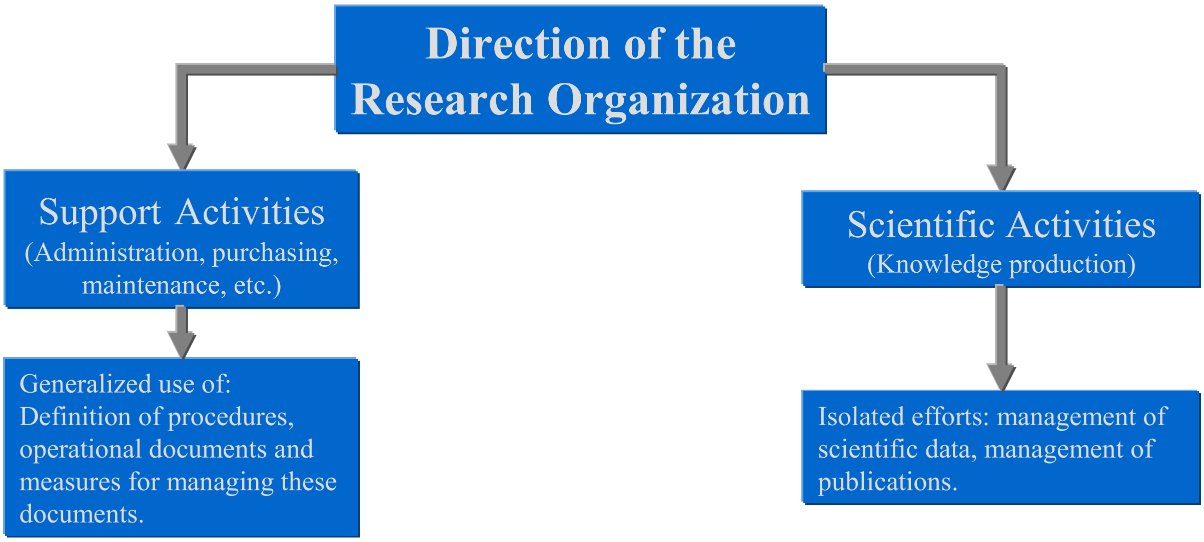

Figure 2. Schematization of the implementation of QMS in the observed research organizations.

In addition, in the laboratory where we have followed the implementation of the QMS, the LAOG, though we tried to start working towards the analysis of scientific activities in order to look for ways of assisting them, this work was not pursued because there were already several aspects on which the QMS was acting. Thus, in this laboratory, the QMS was not acting directly on the activities responsible for the production of knowledge. This means that we have not been able to verify our hypothesis regarding the possibility of using quality management can be used to support the knowledge production process. Conversely, one of the other laboratories we interviewed, the CERMAV, has recently established a working group for the implementation of QM in research activities, particularly on PhD projects, which suggests that QM can indeed be used to support research activities. However, as this work has only recently started (year 2005) and we have only participated in one meeting of the working group, we have not been able to deep into this aspect and therefore we have not included our observations regarding this meeting in the present text.

Thus, although we did not observe a strong influence of the QMS on the knowledge production process, this does not mean that the implementation of this system does not affect the way in which knowledge, in general, and not only scientific knowledge, is managed in the organization. In fact, knowledge is managed in all the activities of the laboratories and not only on the scientific activities. Thus, even if our interest resides on the production of scientific knowledge, the observation of the implementation of the QMS has presented some elements related to the management of the knowledge held by the people of the organization and not only with the documentation of the activity as this implementation could be conceived. For that reason, in the next chapter we will study the subject of knowledge management in order to analyze the way in which the implementation of the QMS has influenced the KM practices of these organizations. The focus is put in the research activities because the objective is the improvement of the process of production of scientific knowledge.

Chapter 3. Knowledge Management in Research Organizations

> "It is evident that you cannot manage knowledge. What you can do is manage an environment that optimizes knowledge. That encourages information sharing, knowledge creation, and team working. An environment that enables creative and supportive interaction between people; that stores, codes, and makes available information in a way that adds value to the individual's work and benefits the organization; and that creates a community of trust and common purpose. To achieve a knowledge environment there needs to be a focus in three areas: preparing the organization, managing the knowledge assets, and leveraging knowledge." (Abell, A., Oxbrow, N.,1999)

3.1 Introduction

When we started our research, our hypothesis was that quality management could be used to support the knowledge production process carried out in research organizations. We expected that the QMS, which we have defined as *"the coordinated activities aimed at improving the realization and the coordination of the actions carried out by a research organization in order to achieve its objectives"*, would define measures to improve research activities. In fact, as one of the fundamental objectives of a research organization is the production of scientific knowledge, we expected the QMS would involve efforts aimed at supporting this process. However, we haven't been able to verify this hypothesis in the case we were following. This doesn't mean it is not true, but at the moment, the process we have followed has not reached the maturity level necessary to address quality in the research process, mainly in the basic research process. As we mentioned in the previous chapter, although the piloting committee initially agreed on forming a working group to address the subject of quality in research, and a first meeting of the group was organized, the activity of the group was not continued given the quantity of initiatives that were already being carried out in the framework of the implementation of the QMS. Thus, the members of the committee decided not to start working on the subject of quality in research until the other initiatives were settled.

Nevertheless, what is important for us is that the personnel in the research organizations perceive the necessity of improving their activities, the central one being the research activity. As this process uses and produces knowledge, we propose to analyze the possibility of using KM in order to improve its realization. KM, which is meant to support the creation of new knowledge (Wunram et al., 2002), could provide tools to assist the production of scientific knowledge. Consequently, we think it can be used to complement the efforts done in the framework of the QMS. For that reason, will present some basic concepts of this discipline[57] and the formal knowledge management practices that have been introduced in the research laboratories we have observed.

3.2 The Knowledge Management Concepts

In order to study the use of Knowledge Management (KM) in the research organizations, we should first understand some basic concepts. This will allow us to clarify the object of our interest, the knowledge issued of research activities, and the existing possibilities to deal with it. For that reason, we will start by defining what knowledge is, before deepening into other aspects of the KM theory.

3.2.1 What is Knowledge?

According to (Croasdell, D.T. et al., 2003), "for centuries philosophers and academics have debated the meaning and role of knowledge. Yet, knowledge has proven to be an evasive term. The inability of researchers to unequivocally define knowledge illustrates this point." For that reason, we think it is necessary to clarify the meaning of the term knowledge, given our interest in the knowledge production process. In order to do so, we have studied some of the explanations found in the KM literature. This literature commonly shows a distinction between data, information and knowledge. Regarding the first two notions, data and information, there seems to be a somewhat consensus about them. In fact several authors

[57] Given the extent of the KM literature we have chosen to limit the scope of this study to this literature. Therefore, the insights coming from other disciplines, such as cognitive science, sociology of science, and others, despite their importance, are not taken into account.

appear to agree in presenting data as signals[58] (Sena, J. A., Shani, A.B., 1999; Beckman, T.J., 1999; Baizet, Y., et al., 2002) or symbols (Croasdell, D.T. et al., 2003), citing as examples, numbers, letters, pictures, or marks in the sand" (Croasdell, D.T. et al., 2003). Information is presented as summarized data (Sena, J. A., Shani, A.B., 1999; Beckman, T.J., 1999; Baizet, Y., et al., 2002) or as symbols structured to provide meaning (Croasdell, D.T. et al., 2003). An example could be the reports used in organizations (Croasdell, D.T. et al., 2003).

Thus, a hierarchy is formed putting data at the lower level, followed by information and finally knowledge at the higher level. However, the notion of knowledge does not show the same consensus. On the contrary, there are several meanings of this concept. We have identified mainly five types of definitions (see Annex 1):

1. Those that present knowledge as a collection of information
2. Those that present knowledge as linked to action
3. Those that present knowledge as beliefs
4. Those that present knowledge as meaning
5. Those that present knowledge as restrictions, heuristics and inference procedures

In the group of definitions presenting knowledge as a collection of information we find examples such as the definitions proposed by (Becker, G., 1999) and by (Sena, J. A., Shani, A.B., 1999).

Regarding the definitions presenting knowledge as the use of information for action, we find definitions such as the ones proposed by Woolf, Turban and Beckman (Beckman, T.J., 1999) that specifically mention problem solving. Other definitions link this concept to action in general, such as the ones proposed by (Weber, F. et al., 2002) and by (Sonnenwald, D. H. et al., 2004).

In the group presenting knowledge as beliefs, we find, among others, the definitions provided by some of the most renowned authors in the field such as (Nonaka, I. et al., 2000), (Wiig, K. M., 1999), (Benbya, H. et al., 2004) and van der Spek and Spijkervet (Beckman, T.J., 1999). The definition proposed by (Frank, C., 2003) also forms part of this group.

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[58] Some readers may be interested in the work of (Shannon, C. E., 2001), who sees signals as the bases of

Another point of view regarding what knowledge is, is the one expressed by (Croasdell, D.T. et al., 2003) who defines it as "meaning based on personal interpretation of inputs."

Finally, we find a conception of knowledge as restrictions, this is the case of the definition provided by Sowa (Beckman, T.J., 1999), who defines knowledge as restrictions, heuristics and inference procedures involved in the modelling of a situation.

After looking into these definitions, we acknowledge some principles regarding knowledge: it is based on information, it involves an interpretative activity and is therefore essentially human, it should be justified and it may enable action. Consequently, we propose the following definition:

> *Knowledge is a temporally stabilized comprehension resulting from interpretations of information, human experience and reflections based on a set of beliefs, which resides as fictive objects in people's minds and is suitable for transformation into actions.*

Other than the discrepancies concerning the definition of knowledge, some authors have proposed different typologies of knowledge. We will now explore some of them.

3.2.2 Knowledge Typologies

According to (Croasdell, D.T. et al., 2003), "part of the difficulty [to unequivocally define knowledge] is the various forms of knowledge that have been identified (e.g., declarative, procedural, tacit, explicit, semantic, etc.)." For that reason, we consider important to briefly present some of the typologies of knowledge that have been specified.:

- Local knowledge, product knowledge and enterprise knowledge: According to (Barthès, J.-P. A., 1997), local knowledge is the one necessary to achieve a precise task. Product knowledge concerns a product and enterprise knowledge is the one used by the directors and concern organizational and strategic aspects.
- Declaratory knowledge and procedural knowledge: (Weil-Barais, 1994, in Simoni, 2001) says that declaratory knowledge "gives information on the objects (real or hypothetical) of

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communication and proposes a mathematical theory of communication.

the world". (Vinck, D., 1997) explains that scientific knowledge "represents the basic example of this kind of knowledge". In addition, according to (Weil-Barais, 1994, in Simoni, 2001) procedural knowledge "gives indications on the procedures and the conditions of utilisation of these procedures".

- Expert knowledge, utilisation knowledge: (Barthès, J.-P. A., 1997) says that utilisation knowledge "is rather knowledge about knowledge and corresponds to the way of using technical knowledge."

These typologies express mostly some types of knowledge according to its object (example: product knowledge, procedural knowledge) or its scope (example: local knowledge). It is then possible that these typologies do not cover the whole spectrum of plausible options. Moreover, their pertinence in the context of research laboratories is not at all clear. However, there seems to be a consensus about the existence of different kinds of knowledge.

In addition, one of the most widely used typologies of knowledge is the one that distinguishes between tacit and explicit knowledge. (Nonaka, I. et al., 2000) explains this typology as follows:

> "There are two types of knowledge: tacit knowledge and explicit knowledge. Explicit knowledge can be expressed in formal and systematic language and shared in the form of data, scientific formulae, specifications, manuals and such like… tacit knowledge is highly personal and hard to formalise. Subjective insights, intuitions and hunches fall into this category of knowledge."

However, (Vinck, D., 1997) argues that knowledge "is due to the context of its production and its use; it is contextualised" and questions the extraction and elucidation of knowledge because of the decontextualization they involve. In addition, (Wegner, 1987) considers organizations as "transactive knowledge systems in which the bulk of knowledge is in individuals' heads, and specialization (among other factors) ensures that each individual maintains different bundles of knowledge." Additionally, (Frank, C., 2003) argues that there is only tacit knowledge because if it is explicit it can be considered information. Our position regarding this subject is based on this vision. We consider knowledge to exist on people's minds, though there are elements that may potentially convey knowledge. Thus, the concept of artifacts seems to us more appropriate[59]. (Norman, D. A., 1992) uses the term "cognitive artifact", and defines it as "an artificial device designed to maintain, display, or operate upon information in order to serve a representational function." He adds that these "cognitive artifacts" are intended to aid cognition and gives as an example the computer. Afterwards, (Hutchins, E., 1999) defined artifacts as repositories of knowledge constructed in durable media, presenting as an example the navigation charts. In addition, (Pomian, J., 2002) defined artifacts as objects or concepts created by the human being. Consequently, we will define knowledge as existing in a tacit form, while the tangible representations of knowledge are designed artifacts. Accordingly, we will retain the following understanding of this term:

> *An artifact is an element having a material form (or a virtual form, as it can exist only in a computer system) which can convey a part of the knowledge held by its author, provided that its receiver knows the context in which it was conceived and has the necessary knowledge for its interpretation. In this sense, artifacts are ways of translating a part of their authors' knowledge in order to give a representation that can be stored and potentially, shared and re-used.*

Consequently, we will only acknowledge the existence of diverse kinds of knowledge, existing in a tacit form, without attempting to define a new typology, and of artifacts, which try to convey knowledge and may take the form of information elements.

We have explained our understanding of what knowledge is. This allows setting the basis for presenting what knowledge management is, which is the subject of the next section.

3.2.3 What is Knowledge Management?

We have stated our interest in improving the support to research activities, together with our hypothesis about possibly achieving it trough KM. It is then necessary to clarify what this term means. For that reason, we have studied some of the definitions found in the literature. According to what we have seen, we consider that there exist mainly four types of visions regarding KM (See Annex 2):

1. Those that see KM as a matter of information technology
2. Those that see KM as a strategic matter

[59] See Chapter 1 Science, section « The role of artifacts ».

3. Those that see KM as a process that facilitates knowledge sharing
4. Those that see KM as a process to create and increase the use of knowledge

In the first group, that sees KM as a matter of information technology we find definitions such as the ones proposed by Stewart and Wiig (In Baek, S. et al., 1999), (Falquet, G., Mottaz-Jiang, C.-L., 2003), Dieng (In Bekhti, S., Matta, N., 2003). This vision seems to us very limited as it treats knowledge as explicit and storable, which is not coherent with the human dimension that is intrinsically involved in the concept of knowledge. (Abell, A., Oxbrow, N.,1999) explain this by saying "knowledge management is about more than technology and databases. It is about connecting people to experts, people to information, and the utilization of that information. It is also about understanding how people learn and making it possible for them to do so, how organizational structures and infrastructures affect the building of knowledge, and how organizational procedures, rewards, and values affect the sharing of knowledge."

In the second group, that sees KM as a strategic matter, we find definitions that concentrate on the result to attain from KM. Among the authors sharing this position, we find: Petrash (KM to make the best decision), Hibbard (KM to produce the biggest payoff), Beckman (KM to enhance customer value), Wiig (KM to maximize effectiveness and returns), van der Spek (KM to achieve company's objectives), O'Dell (KM to create value) (Beckman, T.J., 1999), and (Sena, J. A., Shani, A.B., 1999) (optimization of the firm's knowledge economies). In this group, a strategic objective is linked to the KM activity.

The third group concentrates on the sharing dimension. Some examples are the definitions proposed by: (Huysman, M., Wit, D. de, 2003), Alavi and Leidner (In Benbya, H. et al., 2004), (Swanstrom, E., 1999), Wilma D. Abney (In Haas, R., et al., 2003), Davenport and Prusak (In Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001). In these definitions what prevails seems to be the organizational aspect. In this sense, KM is not limited to information technology but concentrates on the human dimension.

In the fourth group, that sees KM as a process to create and increase the use of knowledge, we find definitions such as the ones proposed by (Grundstein. M., 2002), Spek and Spijkervet (In Baek, S. et al., 1999), Wiig (In Disterer, G., 2002), (Weber, F. et al., 2002) and (Wunram et al., 2002). What distinguishes this group is the vision of KM as a set of activities that foster the use and the creation of knowledge. As we see research organizations as knowledge creating institutions, we consider this point of view to be more coherent with our problematic. In fact, (Wunram et al., 2002) defines KM as "the systematic, goal oriented application of measures to steer and control the tangible and intangible knowledge assets of organizations, with the aim of using existing knowledge inside and outside of these organizations to enable the creation of new knowledge, and generate value, innovation and improvement out of it." From this point of view, KM deals with "tangible and intangible knowledge assets." Similarly, (Abell, A., Oxbrow, N.,1999), (Nonaka, I., et al., 2000) and (Baizet, Y., et al., 2002) express the impossibility of managing knowledge but rather knowledge assets. Complementarily, (Nonaka, I., et al., 2000) position knowledge assets as the basis of the knowledge-creating process, as these are the inputs, outputs and moderating factors of it, and define them as "firm-specific resources that are indispensable to create values for the firm." Consequently, the role of KM is the definition of measures to manage knowledge assets.

An interesting aspect to note regarding this vision of what KM encompasses is that KM results to be similar to the activities performed by research laboratories. One could then see all the activities done by researchers as belonging to the KM domain. However, we do not share this vision. Though we consider the scientific activity to be a knowledge intensive activity, we see the role of KM as a support to the realization of the activities of an organization in order to increase its efficiency[60]. The point of view of (Cross, R., et al., 2001) seems to be similar to ours. For him, KM "is an increasingly popular collection of organizational interventions intended to improve both the efficiency and effectiveness of work in knowledge intensive settings." Nevertheless, we consider KM to be applicable both to knowledge intensive and non knowledge intensive settings. Thus, we will define KM as:

> *The collection of measures intended at increasing the efficiency of the activities performed by an organization through the better utilization of the knowledge assets existing inside and outside the organization.*

Consequently, from our point of view the role of KM in the context of research is the implementation of measures supporting the activities performed by taking advantage, in a

[60] We understand the term "efficiency" as the capability of acting with a minimum of waste, expense, or unnecessary effort. (based on the definition provided by Wikipedia: http://en.wikipedia.org/wiki/Efficiency)

better way, of the knowledge available. The concrete "measures" involved can vary. These may be a matter of networking people and information in order to support the realization of activities through the better utilization of knowledge. Therefore, some authors have proposed KM models in order to define what is concretely involved in KM. These models present the general activities comprised in KM. For that reason, we will briefly discuss these models in the next section.

3.2.4 The KM Models

According to (Steels, 93), the objectives of KM in an organization are to promote knowledge growth, knowledge communication and knowledge preservation in the organization. In order to achieve these objectives several authors have proposed models representing the core activities present in KM. These models decompose the KM question into smaller parts, which (Frank, C., 2003) calls "knowledge manipulation activities". He presents an overview of the different KM Models that have been proposed in the literature, specifying the activities included in the models proposed by: Leonard-Barton, 1995; APQC and Arthur Andersen, 1996; Wiig, 1993; Choo, 1996; Nonaka, 1995; Szulanski, 1996; Romhardt, 1998 and Eppler, 2001. We remit the reader to his work. After this presentation, he proposes a new KM model that comprises the different knowledge manipulation activities of the APQC and Romhardt model. Therefore, we have tried to complement the overview of KM Models with some additional models we have found. In Annex 3 we present Frank's model together with the others we have found.

The analysis of these models allows identifying mainly nine knowledge manipulation activities, which are shown in Table 1. This table presents the main activities we have identified in the KM Models we have seen. It is mostly based on Frank's model, which is the one that specifies the higher number of activities. Though there are some activities that are not exactly the same in all the models, we group them according to the similarity we perceive.

Activity	Other Aspects linked to the Activity				
1. Identify	Location				
2. Acquire	Collect	Capture	Internalize	Retrieval	Review
3. Select					
4. Structure	Organize	Compilation and	Mapping and	Conceptualize	

Activity	Other Aspects linked to the Activity				
		Transformation	indexing		
5. Create	Adapt	Combine			
6. Share	Distribute	Transfer	Externalization	Exchange	
7. Apply	Use				
8. Preserve	Codification				
9. Evaluate	Measurement				

Table 1. Knowledge manipulation activities identified in the KM Models

The activities in the leftmost column of Table 1 could be seen as a metamodel trying to represent the activities that form part of the KM process, without trying to present them in a linear way (Beckman, T.J., 1999)[61].

Nevertheless, this metamodel seems to involve a higher level of detail than what the situation we observe allows us to effectively distinguish. For that reason, we have considered necessary to simplify the model in order to adapt it to the context in which we are interested. In order to do so, we compared the activities in this model to the three stages characterizing the use of bibliographic documents (identification, processing and application)[62], which we consider could represent at least a part of the activities related to the management of knowledge in research organizations. It is then possible to see the similarity between and the activities in the metamodel and the stages characterizing the use of bibliographic documents. Thus, we see a parallel between them, as shown in Table 2:

KM Activities	Use of bibliographic documents
1. Identify	Identification
2. Acquire	
3. Select	
4. Structure	Processing
5. Create	Use
6. Share	
7. Apply	
8. Preserve	Capitalization (Not explicitly involved)
9. Evaluate	

Table 2. Comparison KM activities and Stages in the interaction between researchers and bibliographic artifacts

[61] We note that the activities included are presented according to the order of the activities comprised in Frank's model.

[62] See Chapter 1.Science. Section 1.3.3 The use of bibliographical documents in the scientific activity.

For that reason, we will use as our KM Model, the activities in the right column of Table 2. Consequently, what we would intend to do is to complement the stages already present in the use of bibliographical documentsartefacts, in order to complete the KM Cycle. The idea would be to preserve the traces of the work done, sharing it with other members of the research organisation so that it can be later re-used. The objective is to capitalize the knowledge acquired with the purpose of facilitating the work of researchers during the realization of future activities of identification, processing and (re-)use aimed at the creation of knowledge. As this is the fundamental process of research organizations, we will now present some of the existing claims about it.

3.2.5 The Creation of Knowledge

(Nonaka, I., et al., 2000) define knowledge creation as "a continuous, self-transcending process through which one transcends the boundary of the old self into a new self by acquiring a new context, a new view of the world, and new knowledge… one also transcends the boundary between self and other, as knowledge is created through the interactions amongst individuals or between individuals and their environment." At the heart of the knowledge creation process is the knowledge worker, who produces, refines, and uses knowledge (Swanstrom, E., 1999). According to (Huysman, M., Wit, D. De, 2003) KM calls for support of knowledge workers.

According to (Nonaka, I., et al., 2000), an organization creates knowledge through the interaction between explicit knowledge and tacit knowledge. They define knowledge conversion as the result from the interaction between the two types of knowledge and four modes of knowledge conversion. They are: (1) socialization (from tacit knowledge to tacit knowledge); (2) externalisation (from tacit knowledge to explicit knowledge); (3) combination (from explicit knowledge to explicit knowledge); and (4) internalization (from explicit knowledge to tacit knowledge). These conversions would take place in a never-ending process that upgrades itself continuously.

Though we do not agree with the term "explicit knowledge", we recognize the interaction of people with artifacts and with other people in order to create new knowledge (Nonaka, I., et al., 2000). Furthermore, this knowledge conversion process is mostly accepted as a requirement of knowledge creation. (Sena, J. A., Shani, A.B., 1999) say that the conversion of knowledge from its tacit form to an explicit form "is a social process whereby organizational members engage in a dialogue and gain new perspectives… conflicts and interpretations are resolved – the premises of existing knowledge are questioned and new knowledge is generated." Thus, the conversion of knowledge is intimately connected to the process of knowledge transfer (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002).

At the basis of the creation of knowledge are knowledge assets. (Beckman, T.J., 1999) proposes that in order to transform knowledge into a valuable organizational asset, knowledge, experience, and expertise must be formalized, distributed, shared, and applied. On the other hand, (Nonaka, I., et al., 2000) propose a model of knowledge creation consisting of three elements: (i) the SECI process, the process of knowledge creation through the conversion between tacit and explicit knowledge, (ii) ba, the shared context for knowledge creation; and (iii) knowledge assets -the inputs, outputs and moderators of the knowledge-creating process. They categorise these assets into four types: experiential knowledge assets, conceptual knowledge assets, systemic knowledge assets and routine knowledge assets. They define them as follows:

1. Experiential knowledge assets consist of the shared tacit knowledge that is built through shared hands-on experience amongst the members of the organization, and between the members of the organization and those belonging to other external organizations with which the organization interacts[63].
2. Conceptual knowledge assets consist of explicit knowledge articulated through images, symbols and language.
3. Systemic knowledge assets consist of systematised and packaged explicit knowledge.
4. Routine knowledge assets consist of the tacit knowledge that is routinised and embedded in the actions and practices of the organisation.

According to these definitions, the first and fourth types of knowledge assets present a tacit form, while the second and third types would correspond to what we have defined as artifacts. These knowledge assets are transformed in Ba, where knowledge is shared, created and utilised. Ba is also defined as a time-space nexus in which information is interpreted to

[63] The original text of (Nonaka, I., et al., 2000) specifies "customers, suppliers and affiliated firms" when defining experiential knowledge. We have preferred to talk about "other external organizations with which the organization interacts", to adapt the definition to the context of research organizations.

become knowledge. Thus, a basic difference between information and knowledge, is that the latter is context-specific[64], as it depends on a particular time and space (Nonaka, I. et al., 2000).

In addition, (Nonaka, I., et al., 2000) define four conditions favourable for the creation of knowledge, that are also related to the access to information. They are:

1. Autonomy, which increases the chances of finding valuable information and motivating organisation members to create new knowledge.
2. Creative chaos, which stimulates the interaction between the organisation and the external environment, and helps to focus members' attention and encourages them to transcend existing boundaries to define a problem and resolve it.
3. 'Redundancy', which refers to the intentional overlapping of information[65]. Redundancy of information speeds up the knowledge-creating process in two ways. Firstly… promotes the sharing of tacit knowledge…. Secondly… helps organisational members understand their role in the organisation. A less positive effect is that redundancy of information does increase the amount of information to be processed and can lead to information overload.
4. Requisite variety, which helps a knowledge-creating organisation to maintain the balance between order and chaos. It can be enhanced by combining information differently, flexibly and quickly, and by providing equal access to information throughout the organisation… An organisation's members should know where information is located, where knowledge is accumulated, and how information and knowledge can be accessed at the highest speed.

Consequently, what seems to be the fundamental aspect for the creation of knowledge is connecting people to people, people to information, and providing a means to develop the [tacit] knowledge required to effectively utilize information (Abell, A., Oxbrow, N., 1999). In order to achieve this, different approaches have been developed to support this process. We have observed what we consider are mainly two types of approaches:

1. Those that support the organizational aspects in order to improve the knowledge held by the personnel of the organization
2. Those that support the informational aspect in order to provide explicit representations of the knowledge available in the organization.

These approaches are not mutually exclusive but can complement each other (Alsène, E., et al., 2002). In the first one, the focus is on the management of the competencies of the people

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[64] See also (Vinck, D., 1997).

[65] (Nonaka, I., et al., 2000) specifies overlapping information about business activities, management responsibilities and the company as a whole.

of the organization. In other words, the capacity they have to act at a given situation (Alsène, E., et al., 2002; Baizet, Y. et al., 2002; Grundstein, M., 2002). However, as one of the situations we have observed in research organizations is the constant turnover of personnel, we have considered that solely concentrating on this aspect would not be very appropriate for research organizations. On the contrary, the second approach, which focuses on the information, seems to be well fitted to our context, given the importance that information (particularly documents) has in research organizations (Latour, B., Woolgar, S., 1986). In this approach, the work usually aims at the construction and actualization of an organizational memory in order to facilitate the access to information. This is the subject we will present in the next section.

3.2.6 The Organizational Memory

The term organizational memory is also referred to as enterprise memory or corporate memory. As we want to focus on research organizations, we will adopt the more general term of organizational memory (OM). (Sonnenwald, D. H. et al., 2004) define a memory as a "persistent record not dependent on a tight coupling between sender and receiver" because transmission is one way and temporal distance is significant. In the research context, this is very important because the nature of the work makes it often necessary to rely of knowledge that may be geographically of temporally distant.

Nevertheless, as with other concepts in the KM domain, the concept of OM also counts with several definitions. Thus, (Huber, G.P., T. H. Davenport, and D. King, 1998) define it as "the set of repositories of information and knowledge that the organization has acquired and retains." Alternatively, (Croasdell, D.T. et al., 2003) defines OM as "the means by which knowledge from the past is brought to bear on present activities resulting in higher or lower levels of organizational effectiveness." Additionally, (Barthès, J.-P., et al., 1999), based on the definition proposed by (Van Heijst, G., et al., 1996), define organizational memory "as the explicit and persistent representation of knowledge and information in an organization, in order to facilitate their access and their re-use by the appropriate members of the organisation for their task." Given our conception of what knowledge is, the latter is the definition we will retain.

In addition, according to (Dieng, R. et al., 1999) this memory should provide "the right knowledge or information to the right person at the right moment and the right level so that this person can take the right decision"[66]. In order to achieve this goal, some authors have defined the necessary stages an organization should perform in order to build its organizational memory.

(Dieng et al., 1998) propose the following stages: Detection of the requirements, Construction, Diffusion, Use, Evaluation and Maintenance and evolution. Alternatively, (Sonnenwald, D. H. et al., 2004) define the following processes of organizational memory: Acquisition, Retention, Maintenance, Retrieval. Anyhow, the basic idea is to preserve knowledge for later re-use (Sonnenwald, D. H. et al., 2004; Barthès, J.-P., et al., 1999; Grundstein, 1995; Pomian, J., 1996) making possible the process of knowledge capitalization. (Simon, G., 1996) defines it as the process that allows to reuse, in a relevant way, the knowledge of a given domain, previously stored and modelled, in order to perform new tasks. In consequence, it is necessary to locate it, keep it, bring it up to date and make it available to the people in the organization (Barthès, J. P., et al., 1999). That is the reason why, though informal networks of people may be a means to maintain the organizational memory, the construction of this memory mostly concentrates on managing information, which is storable and potentially retrievable by using information systems designed for this (Sonnenwald, D. H. et al., 2004; Falquet, G., Mottaz-Jiang, C.-L. 2003; Barthès, J.-P. A., 1997; Bénel, A., et al., 2002; Conklin, J., 1996). Accordingly, (Croasdell, D.T. et al., 2003) uses the notion of Organizational Memory System (OMS) and defines it as "the processes and IS [Information Systems] components used to capture, store, search, retrieve, display, and manipulate OM."

Besides the different definitions provided in the literature regarding OM, some authors differentiate some types of memory. (Barthès, J.-P., et al., 1999) propose to distinguish: Internal memory, corresponding to knowledge and internal information of the enterprise and External memory, corresponding to knowledge and useful information for the enterprise, but coming from the external world. In addition, (Pomian, 1996, cited by Barthès, J.-P., et al., 1999), specifies: "technical memory" obtained from the capitalization of the know-how of its

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[66] See also (Junnarkar, B., 1997).

employees, “managerial memory” leaning on the past and present organisational structures of the enterprise (human resources, management, etc...) and “project memories” for capitalizing lessons and experiences of certain projects. As the research activity is mainly done through projects (Vinck, D., 1995), this type of memory is the one that interests us the most. For that reason, we will hereafter deep into it.

3.2.6.1 The Project Memory

According to (Vinck, D., 1995), in science “the sequence of activities performed is hardly observable and usually differs from the formal descriptions of procedures, methods and work schemes.” This means that the conception of projects as temporary organizations with specific objectives, detailed tasks, and restricted time and budget (Disterer, G., 2002) do not fit in this particular context. In fact, projects in science may not have well delimited boundaries (in terms of objectives, tasks, people, time and even budget). At the beginning of the project the boundaries may, and usually are, fuzzy. Their delimitation is achieved as the project advances. Consequently, in science, projects are temporary organizations aimed at studying a phenomenon, but whose boundaries may not be completely defined from the very beginning.

The temporal dimension of projects is at the origin of some of the identified difficulties for the capitalization of knowledge in project environments (Disterer, G., 2002; Pomian, J., Roche, C., 2002). Among these difficulties are the problems for building on previous experiences, difficulties for retrieving the information and even for contacting the people that participated in a specific project. Accordingly, (Vinck, D., 1995) notes that, in science, the tacit competences that allow the realization of activities result very important, together with the access “to the history of the procedure by which the phenomenon is made visible”, which may be difficult to attain.

In order to overcome these difficulties, some authors have proposed the construction of project memories. The objective is to avoid “reinventing the wheel’’ through the sharing of existing knowledge and experiences (Disterer, G., 2002). In accordance with this position, Matta (Bekhti, S., Matta, N., 2003) define a project memory as a representation of the experience acquired during projects realization. According to (Bénel, A. et al., 2002) organizational memory allows sharing knowledge among individuals working alone, by teams needing a project memory, and by the organization as a whole for between-team coordination and communication. They remark the importance of capturing knowledge in a transparent way, as a basic condition for the sustainability of the memory. In this sense, motivating the personnel to actively participate in the construction of the memory implies avoiding, as much as possible, imposing extra work and clearly showing the benefits this memory can bring to individuals in the organization.

According to (Dieng, R., et al., 2000), the elements taken into account in a project memory should be:

- The organization of the project, the participants, their competences, their organization in sub-teams, the assigned tasks, etc.
- The reference frames (rules, methods, laws, etc.) used for developing the stages of a project.
- The development of the project, the resolution of problems, the evaluation of solutions, as well as the management of the incidents occurred.
- The main objective of the project, the global strategy that guides decision-making, as well as the results obtained from the concretization of the decisions.

The documentation of these elements may be attained through different means. (Disterer, G., 2002) mentions as tools for documenting project knowledge: Debriefing sessions aimed at identifying and capturing new knowledge and preparing the knowledge for knowledge transfer to other projects; project profiles, which cover project characteristics and summaries and “yellow pages” that provide information about the person to contact for a specific problem. In addition to these methods, the KM literature presents other ones aimed at supporting the development and surfacing of knowledge that is shared in organizations (Huysman, M., Wit, D. de, 2003). In the next section, we will briefly present some of these methods.

3.2.7 The KM Methods for building organizational memories

The majority of KM methods aim at defining an organizational memory (Bekhti, S., Matta, N., 2002). They distinguish two categories of KM methods: knowledge capitalization methods and direct extraction methods:

1. The knowledge capitalization methods use primarily techniques of knowledge engineering. These techniques consist mainly of knowledge extraction (interviews to experts or collection from documents) and modelling.
2. The direct extraction methods aim at extracting knowledge directly from the activity of the organization. We can distinguish several techniques as data mining, text mining, techniques of traceability, and design rationale.

3.2.7.1 The Knowledge Capitalization Methods

Among the knowledge capitalization methods (Dieng, R., et al., 2000) distinguishes the MKSM, CYGMA, FX Workshop, REX, Merex, Componential Framework, CommonKADS and KOD Methods. Annex 4 contains a table summarizing some of their main characteristics.

These methods aim at capitalizing knowledge of a specific domain or activity. To capture this knowledge most of them use interviews to experts and analysis of documents that will later be used for producing models or other kinds of representations of the knowledge to be capitalized. In addition, the majority of them use software tools to support, in some cases, the representation of the elements taken into account and the retrieval of the information contained in these systems. We consider these methods most suitable for capturing the knowledge that has already become stable. This differs from the situation we want to support, which is the creation of knowledge through basic research activities. For that reason, we will present hereafter the direct extraction methods, which aim at extracting knowledge from activities, as they are performed in the organization.

3.2.7.2 The Direct Extraction Methods

As we have mentioned, we are mostly interested in project memory and therefore in the approaches of knowledge capitalization in this kind of memory. An important part of these approaches aims at capturing the design rationale of design projects. Design rationale is an explanation of why an artefact, or some part of an artefact, is designed the way it is. In a design process, design rationale is captured by recording reasoning, decisions, options, tradeoffs, etc., and constructing a formal or semi-formal structure so that the design rationale can be used in the decision-making process during design (Regli, W.C., et al., 2000).

These methods allow keeping track of collective problem solving, especially those extracted in meetings of decision-making, representing the reasoning and argumentation occurring in design (Bekhti, S., Matta, N., 2002; Regli, W.C., et al., 2000). Many design rationale methods apply a representational approach, which uses a semi-formal graphical format for laying out the structure arguments. It uses a node-and-link representation, which means it uses typed links to interconnect typed nodes. The most common argument structures for selecting and organising information are IBIS, PHI, QOC and DRL (Regli, W.C., et al., 2000), among others. The table presented in Annex 5 summarizes some of the main characteristics of these methods.

Most of these methods represent the design process as a series decisions taken to solve problems, presenting the alternatives formulated and, in some cases, the criteria to qualify the alternatives. In this way, the project memory includes not only the retained solutions, but also the discarded ones, together with the arguments used to support or to object them. Their application demands structuring exchanges and add work to the project activities. For that reason, we consider difficult their application in the context of basic research.

In addition to the KM Methods, there exist interesting software developments aimed at supporting the management of knowledge in the organizations. In the next section, we will briefly explore some of them.

3.2.8 The KM Systems

Knowledge management systems (KMS) are defined as “technologies that support knowledge management in organizations, specifically, knowledge generation, codification, and transfer” (Benbya, H., et al., 2004) or as “the tools and processes used by knowledge workers to identify and transmit knowledge to the knowledge base contained in the OM” (Croasdell, D.T. et al., 2003). They aim at providing a way to represent and access to knowledge in all forms, that is both explicitly documented knowledge and knowledge held by individuals (Yiman Seid, D., Kobsa, A., 2003; Szulanski G., 2000; Wunram M., et al., 2002). The objective is to “reuse of knowledge created by knowledge workers” (Huysman, M., Wit, D. de, 2003).

3.2.8.1 The types of KM Systems

The software used for KM is defined by (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001) as “a kind of software that supports any of the three basic KM processes (Davenport & Prusak, 1998): generation, codification and transfer.” They propose a typology of KM categories consisting of[67]:

- Intranet-based systems[68]
- Electronic document management (EDM)
- Groupware
- Workflow
- Artificial intelligence-based systems
- Business intelligence (BI)
- Knowledge map systems
- Innovation support tools
- Competitive intelligence tools
- Knowledge portals

These tools strive at mainly four aspects: connecting people, storing and retrieving documents, supporting organizational processes and problem-solving and analysing information. The recognition of the importance of these systems varies from one system to the other. Thus, while the role of expert systems and other intelligent systems has been questioned, “there is strong agreement about the value of global computer networks and

[67] (Benbya, H., et al., 2004) present a different typology, including broader types of KM systems. It differentiates: Content management tools (to integrate, classify, and codify knowledge from various sources), Knowledge sharing tools (that support sharing knowledge between people or other agents), Knowledge search and retrieval systems (that enable search, retrieval and knowledge discovery) and General KMS (that propose an overall solution for a company’s knowledge management needs).

[68] A brief explanation about each type of system is presented in Annex 6.

groupware for knowledge sharing" (Beckman, T.J., 1999). In fact, some authors claim that the real value of these systems "is rather in connecting people to people" (Wunram M., et al., 2002) in order to allow knowledge sharing (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001). The reason is that documents represent only part of the knowledge of the organization (OECD, 1998). This shows a different approach to KM, where the objective is no longer building a knowledge repository[69], but also allowing people to directly share knowledge in order to create new knowledge.

In addition, it has also been recognized that these systems, by themselves, do not assure the effective support to KM. Thus, (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002) remark the importance of having committed, motivated and skilful members in the organization, that is willing and able to share and apply information in a useful manner. (Erickson, T., Kellogg, W. A., 2003) claim that these systems "must take into account, either explicitly or implicitly, the social context within which knowledge is produced and consumed." Consequently, supporting KM would require KM Systems and getting people to effectively use these systems.

At the base of these systems, there are conceptualizations of the environments for which the systems are intended. According to (Mizoguchi, R., et al., 1997), "the new generation AI [Artificial Intelligence] systems should be built based on a conceptualization represented explicitly." Thus, since Gruber defines ontology as an "explicit specification of a conceptualization" (Mizoguchi, R. and Bourdeau, J., 2000; Dieng, R., et al., 2000), we will hereafter briefly present some basic elements regarding ontology.

3.2.8.2 Ontology as a support to KM Systems

Several definitions have been proposed for the term ontology[70]. Some of them describe it as the definition of relations among terms, concepts or objects (Bekhti, S., Matta, N., 2003; The

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[69] According to (Beckman, T.J., 1999) "a knowledge repository is an on-line, computer-based storehouse of expertise, knowledge, experience, and documentation about a particular domain of expertise. In creating a knowledge repository, knowledge is collected, summarized, and integrated across sources."

[70] Though the term « ontology » is originally used in philosophy, we present here the meaning it has taken in the field of knowledge engineering. Annex 7 presents the definitions we have identified.

Standard Upper Ontology Working Group; Becker, G., 1999). Other definitions introduce the use of formal models or languages in order to define these relations (Buckingham Shum, S., et al., 1999; Falquet, G., et al., 2003; Mizoguchi, R., and Kitamura, Y., 2000; Liao, S-H., 2003). Finally, some authors present ontology as a conceptualization (Van Heijst, G., et al. 1997a; Guarino and Giaretta, 1995, cited by Dieng, R., et al, 2000).

It is also interesting to know what ontology is not. Thus, (Mizoguchi, R. and Bourdeau, J., 2000) state: "Ontology is not the total knowledge of the target world but is a backbone/skeleton of the target world". It can help people "identify what they agree on and what they do not" (Mizoguchi, R. and Bourdeau, J., 2000).

In addition, (Falquet, G., et al., 2003) state that the two processes involved in the construction of ontology are: "formalization of the definitions and "consensualization" on these definitions. The formalization of definition consists in transforming a textual (natural language) definition into a formal one." "Consensualization consists in trying to reconciliate those different viewpoints in order to get a coherent ontology" (Falquet, G., et al., 2003)"

Consequently, ontology could be defined as:

> *The explicit, formal and consensual specification of concepts and their relations, in order to describe a part of reality.*

This specification can be done at different formalization levels. Accordingly, Mizoguchi proposes three levels of ontology (Mizoguchi, R. and Bourdeau, J., 2000):

1. Level 1: "A structured collection of terms. The most fundamental task in ontology development is articulation of the world of interest, that is, elicitation of concepts and identifying the so-called is-a hierarchy among them…. Little definition of the concepts is made."
2. Level 2: "We can add formal definitions to prevent unexpected interpretation of the concepts and necessary relations and constraints also formally defined as a set of axioms. Relations are much richer than those at the level 1… Definitions are declarative and formal to enable them to be interpretable by computers."
3. Level 3: "The ontology at this level is executable in the sense that models built based on the ontology run using modules provided by some of the abstract codes associated with concepts in the ontology."

Along with these categories, level 1 ontology corresponds mostly to a taxonomy, where classes of objects and the relationships among them are defined (Bekhti, S., Matta, N., 2003; Becker, G., 1999).

According to (Van Heijst, G., et al. 1997a), ontology can be classified according to two dimensions: the amount and type of structure of the conceptualization and the subject of the conceptualization. Regarding the first dimension, (Van Heijst, G., et al. 1997a) distinguish three categories: 1)Terminological ontology, that specify the terms that are used to represent knowledge in the domain of discourse, 2) Information ontology, that specify the record structure of databases and 3) Knowledge modelling ontology, that specify conceptualizations of the knowledge.

Regarding the typology of ontology according to the subject of the conceptualization, (Van Heijst, G., et al. 1997a) distinguish: 1) Domain ontology, that express conceptualizations that are specific for particular domains; 2) Generic ontology, that are similar to domain ontology, but the concepts that they define are considered to be generic across many fields; 3) Application ontology, that contain all the definitions needed to model the knowledge required for a particular application (they usually are a mix of concepts taken from domain ontology and from generic ontology); and 4) Representation ontology, that provide the primitives used for describing domain ontology and generic ontology.

Among the advantages of ontology, (Mizoguchi, R., and Kitamura, Y., 2000) indicate: the definition of a common vocabulary, the explication of aspects usually left implicit, the provision of the building blocks on the model of the target represented. Despite these advantages, (Loregian, M., Telaro, M., 2004) claim that the classical way of building ontology cannot be applied to "a context where the knowledge base, and the underlying ontology in particular is dynamically defined." Thus, they suggest asking the people involved "to engage themselves in a dynamic process of collective negotiation" (Loregian, M., Telaro, M., 2004). In a similar way, (Becker, G., 1999) states the need to build flexible and extensible ontology, in order to handle the changes that will appear. Consequently, the construction of ontology for the research activity, particularly of domain ontologies, where knowledge is continually evolving, needs the definition of a flexible approach that allows researchers to develop it dynamically. In addition, the need for consensus should also be questioned when talking about scientific knowledge. The condition of "redundancy"[71] stated by (Nonaka, I., et al., 2000) as favourable for the creation of knowledge, could be interpreted in the scientific context as the knowledge about the different positions and approaches existing about a same scientific question. Mainly during the "Normal Science" period, where questions have not been completely settled and scientists propose different approaches for treating a same question[72]. Thus, a level 1 ontology could be possibly built, but the definition of a level 2 ontology would need the acceptance of a paradigm[73]. This level 1 ontology could possibly help allowing the "Requisite variety" [74] (Nonaka, I., et al., 2000) recommend as another condition for favouring the creation of knowledge. Consequently, though we consider the concept of ontology as important for the organization of information about the existing knowledge, its application in the scientific domain needs adapting it to the conditions and necessities of the activity.

With this section, we finish the presentation of what we consider are the basic concepts of Knowledge Management. Thus, we defined knowledge as existing in people's heads and artifacts as the material (or virtual) elements trying to convey knowledge. We also explained our understanding of what KM involves by defining it as the measures to increase efficiency through the better utilization of knowledge assets. In addition, we defined as our KM model involving the following aspects: Identification, processing, use and capitalization. Then, we saw how the fundamental aspects for the creation of knowledge seems to be connecting people to people, people to information, and providing a means to develop the [tacit] knowledge required to effectively utilize information. For that reason, we have deepened into the subject of organizational memory, particularly on the project memory, for whose constitution different methods and tools have been proposed in the KM literature.

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[71] See section 3.2.5 The Creation of Knowledge.

[72] (Kuhn, T., 1996) explains that normal science is an enterprise that "aims to refine, extend, and articulate a paradigm that is already in existence." He adds: "Paradigms are not corrigible by normal science at all. Instead… normal science ultimately leads only to the recognition of anomalies and to crises." Complementarily, (Vinck, D., 1995) explains that the accumulation of abnormalities and of incoherencies leads to exceptional periods of crisis where the paradigm is progressively questioned, resulting in the quest for new paradigms. Thus

[73] See Chapter 1. Science, section 1.2.2 The aspects involved in the construction of facts.

[74] See section 3.2.5 The Creation of Knowledge.

This has helped us understand the available developments in this field. As we have mentioned, the main purpose of research organizations is the production of knowledge. Consequently, we have been interested in knowing if the KM developments were formally used by these organizations, or if the introduction of quality management could promote the incorporation of KM practices into the research activity. In the next section, we present our observations regarding the formal use of KM in research organizations.

3.3 The Use of KM in Research Organizations

If one takes the objectives of knowledge management, as defined by (Steels, 1993), as being "to promote knowledge growth, knowledge communication and knowledge preservation", it is not difficult to see the coincidence with the role one could define for research organizations. For this reason, we will now present the knowledge management practices introduced through the implementation of quality management in a group of research organizations.

3.3.1 The Formal Use of KM

In spite of the coincidence between KM objectives and those one could state for a research organization, when asked about KM practices, the research laboratories observed recognized not formally using them, though they acknowledged being interested in their application given their possible positive impact on the organization. This does not mean that these organizations do not have implemented practices favoring the creation of knowledge, but that they do not do it within the framework of the claims done in the KM literature. This means, that there are no formal initiatives regarding the management of knowledge. However, the laboratories have indeed implemented practices for managing knowledge. At the ACROE, for example, every post-graduate student is requested to leave a binder with a copy of all the registers and documents used and produced during his work at the laboratory. In addition, all the creations[75] are carefully indexed and organized as a means of keeping trace of the work and having the possibility of reusing them later. Other organizations have worked on the communication of the publications made by members of the laboratory, mostly through their

[75] This laboratory work on the use of informatics for the artistic creation, mostly music and animation of designs.

Web Sites. This allows visibility of their production outside of the laboratory, which is considered important for promoting exchanges with other researchers. An example of the work on the publications is the LIS[76] that publicizes a list of its yearly publications. Also, the CERMAV[77] allows accessing a database where the references of the publications made by its members can be consulted. In addition, this laboratory has worked on the organization of databanks with information on the macromolecules, which is the base of its work. Similarly, the LECA[78] has worked on the implementation of a database where the publications made by the researchers are signaled.

These initiatives come mainly from the needs of the activity than from the implementation of quality management. Only in the case of the LECA, the quality management project was at the origin of the work on the publications of its researchers. Therefore, it is not clear what is the role played by quality management regarding the management of knowledge or even if it does indeed play a role at all. In addition, practices related to the management of knowledge have been implemented before the start of the quality management projects. Thus, it is conceivable that formal KM practices could be implemented independently from quality management. The question is then if quality management can benefit the implementation of KM, particularly for basic research activities. Consequently, in the next section we will look into the activities related to the construction of the organizational memory resulting from the implementation of quality management.

3.3.2 The Organizational Memory of Research Organizations

The idea behind the concept of organizational memory is facilitating the capitalization of knowledge by the members of the organization, in our case a research organization. Thus, one could expect that the organizational memory be focused on the research activity. However, we have not seen a very strong relation between the quality management implementation and the

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[76] Image and Signals Laboratory – Laboratoire des Images et des Signaux : http://www.lis.inpg.fr/ind_recherche.html

[77] Research center on the Vegetable Macromolecules - Centre de Recherches sur les Macromolécules Végétales : http://www.cermav.cnrs.fr/cgi-bin/biblio/biblio.cgi

[78] Laboratory of Alpine Ecology - Laboratoire d'Ecologie Alpine: http://www2.ujf-grenoble.fr/leca/infos.html

construction of an organizational memory related to the research activities. Actually, we have seen that the implementation of quality management is used mainly for support activities. In other words, there is an effort of formalization and capitalization of the organizational memory for support activities, which is not accompanied by a similar effort for scientific activities. In these activities, the related know-how corresponds to the knowledge of the way of carrying out research projects and the activities that allow them to take place. This know-how has traditionally formed part of the tacit competences[79] of researchers and is consequently not formalized. Additionally, scientific knowledge is the main raw material used, mobilized by the creativity of the researcher. Therefore, the principles that try to organize research activities, or part of them, can be perceived of as being non-applicable because they could be seen as constraining and/or opposite to imaginative creation[80].

According to the (AFNOR, 2000), a process is a "set of interrelated or interacting activities which transforms inputs into outputs". We can then see scientists as knowledge workers who are in charge of performing the research process. This process uses as main raw material (as input) the knowledge and information accessible to the researchers, internally and externally, in order to produce new knowledge and information (the output of the process). Thus, the research process could be represented by Figure 3.

In this sense, we find pertinent the typology of organizational memory suggested by (Dieng et al., 1999). This typology distinguishes between the internal memory and the external memory. Consequently, the accomplishment of the research process could be related in a very important way to the researchers' access to both of these memories and to their capacity to mobilize them. However, in the observed laboratories little is done in order to facilitate the access to these memories.

[79] See (Vinck, D., 1995)

[80] For example, Mr. Desrues, Director of Research at the 3S Laboratory, says: "We have thought about what was quality in basic research, for example… It is true that this is not easy to marry, because quality can be seen like very normative and research like anti-normative by definition." (Extracted from the report of the interview made on May, 13th, 2002).

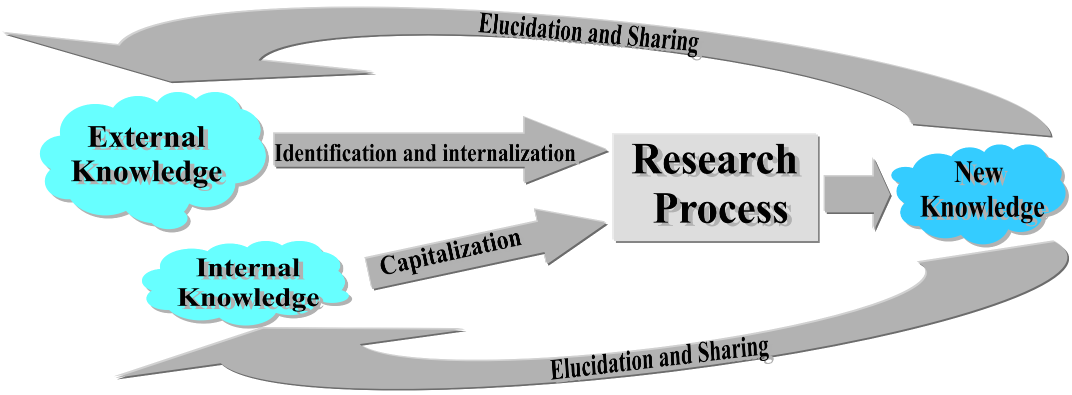

Figure 3. The research process

Regarding the external memory, the CERMAV has included in its Intranet some information regarding the information sources available to its members (i.e., the information on the databases accessible for obtaining bibliography). Also, the LIS has included information on the important scientific conferences for its research field. Additionally, the LCMI has included in its information system the standards considered important for their activity. The other laboratories have focused on aspects different from the access to the "external memory"[81]. An important remark is that the organization of the scientific network to which the organization belongs influences the importance granted to providing information about external information sources. Thus, according to the LAOG, for them, the information on the principal journals is not regarded as important because in their field, astrophysics, the principal journals are only a few (according to them there are only three)[82].

Regarding the "internal memory", in most cases it is not clearly structured, which make even harder accessing it. Nevertheless, within the framework of the quality management initiative, some laboratories have worked on the structuring of specific aspects important for the research activity. Thus, the CERMAV and the LIS have worked on the development of databanks with information about scientific data used in the research activities. On the other hand, the LAOG has detected difficulties linked to the numerical codes developed at the

[81] This information was extracted from the report of the interview of April, 24th, 2002.

[82] This information was extracted from the report of a meeting of the working group of the subject Quality in Research held on April, 7th, 2003. An important remark is that this group did not pursued its work because the laboratory decided to have a better implementation of the aspects related to the quality management in the support activities, before dealing with the research activities.

laboratory, which instead of being re-used are re-developed given the unawareness of previous developments made by other research teams. Similar situations have been detected at the ACROE – ICA, where part of one of the software programs developed internally had to be repeated given the impossibility of understanding the existing code in order to improve it[83].

It would then be desirable to incorporate measures to facilitate the researchers' access to the external and internal memory. Furthermore, as research activities are mostly organized in projects (Vinck, D., 1995), a very important aspect regarding the internal memory is the organization of the project memory. We will hereafter briefly explore this aspect in the next section.

3.3.2.1 The Project Memory in Research Organizations

Though the project memory could be the most important aspect in research organizations, we have not seen many efforts regarding the structuring of this memory. In fact, in most cases, the management of projects presents practices that vary from one project to the other, inside a same organization. Thus, the records of the projects vary in the same way, mainly in the basic research activities. Only at the 3S laboratory, there was an explicit effort to structure the follow-up of the research projects of the Geo-mechanical research unit through the establishment of a process based on the documentation of some aspects along the development of the project. Nevertheless, this initiative was not embraced by all the personnel. In addition, the researcher responsible for the implementation of the QMS recognized the existence of problems to keep up this initiative because it demanded reminding the personnel about it. This, he explained, was difficult for him due to time constraints linked to the fact that his primary function was as a researcher and the work on QM was additional to it.

Additional examples are the LCMI and the SERAS, which work on applied research and develop technical activities. These organizations have made important efforts for structuring the documentation of their projects. For this purpose, both organizations have relied on the implementation of Electronic Document Management – EDM systems that allow keeping the

[83] This information has been extracted from the report of the meeting held on April 13th, 2002 at the ACROE-ICA within the framework of the observation done at this laboratory.

records of all the projects in a structured way. Though this could be seen as a project memory, aspects such as the design rationale are not explicitly treated.

These examples show efforts for structuring a part of the information generated by the activities of these organizations. However, the objective is not just storing information but being able to build on the experiences lived. In other words, the objective is being able to capitalize the knowledge acquired through the realization of the activities of the organization in order to re-use this knowledge. This introduces us to another important issue, which is the capitalization of knowledge. We will discuss this subject in the next section.

3.3.3 The Capitalization of Knowledge

The methods for capitalizing knowledge focus on the capitalization of knowledge from a specific domain, activity or process. This capitalization is supported by aspects such as technical data management, document management and know-how formalization (Grundstein, M, 1995). It is thus interesting to analyze the way in which these aspects are present in the research organizations we have observed to look how the implementation of quality management has contributed to the capitalization of knowledge.

The quality management systems implemented, in the research organizations studied up until the time of writing this document, started with the objective of improving the organizational aspects. This is done mainly through written documentation (operational procedures and processes), where an important aspect is the writing process itself. In fact, quality management, and mainly the ISO 9000 standard, usually stands on the paradigm of *"to write what you do and then do what you write"* (Bénézech, D., et al., 2001). However, the process of writing implies not only just writing but also analyzing the current practices of the organization. In addition, since the objective is to state the way processes are performed in the organization, it requires working in teams where the members involved in the process participate. This work serves to analyze the way processes are done and elucidate the stages involved.

We have noticed two aspects in this process: First, there is an important unawareness of the processes of the organization. Thus, while analyzing how processes are done, team members may discover parts of it and understand why it is structured the way it is. Second, the analysis of processes helps uncovering constraints and improvement opportunities that sometimes lead to modifying the process at the same time it is being explicitly described[84]. Consequently, the work of writing what the people in the organization does, usually requires time and effort before arriving to a document validated as part of the quality management system. Through this process, parts of knowledge held by individual members of the organization are externalized, shared and elucidated. The purpose is allowing other members of the organization benefit from it. Thus, though either one of the KM Methods described in the literature is formally applied, there are similarities such as the writing, validation and sharing of documents in order to profit from the experience of the members of the organization.

These documents could be considered as the formalization of the know-how related to some of the processes of the organization. Thus, we consider that implementing quality management means formalizing at least a part of the know-how used by the employees of an organization. In the research organizations we studied and where we performed interviews, this has been mostly done for the administrative activities, such as purchasing or contracting. In contrast, this has not been yet addressed to research activities, which continue to function mainly with little formalization of the related know-how. Thus, quality management could be seen as a methodology that supports the elucidation of routine knowledge, in order to contribute to the better management of the knowledge assets of the organization.

An exception is the LCMI, where the work focused on the technical aspects and not so much in the administrative ones[85]. For LCMI, the quality management implementation resulted in documenting the activity of the technical personnel. The aspects documented are of four types: Instructions about the use of the documentary system itself, operational documents related to the activity of the technicians, documents related to the management of process comprising from the design to the construction of the equipments (magnets)[86], and other

[84] This is coherent with what (Bénézech, D., et al., 2001) express about the ISO 9000. According to them, “the ISO 9000 family can be viewed as a tool to gain an understanding about products and processes, even if it does not solve existing problems by itself.”

[85] This information has been extracted from the report of the interview made on April the 24th, 2002.

[86] This work was only starting at the moment of the interview.

documents related to more transversal issues (i.e., safety and continuing education). All these documents try to elucidate technical knowledge in order to improve the activities. However, this elucidation has been done only for design projects and not for basic research projects. In fact, this process has not concerned, at all, the personnel involved in basic research.

An aspect common to all of the experiences we have observed is the reliance on information systems for the management of the documents produced. Therefore, we will explore hereafter the relationship that could be established with the KM systems.

3.3.4 The Use of KM Systems

Quality management systems have been translated into information systems, so that the documents resulting from its implementation can be shared. These information systems are often an Intranet that sometimes manages other documents of the organization. This verifies what (Gandon et al., 2002a) say about the use of Intranets and the Web as means to manage documentation. However, the information systems that we have observed have only been used for the management of the documents directly related to the quality system. Unlike the aim of projects like CoMMA (Gandon et al., 2002), they do not have as an objective "the management and the circulation of distributed knowledge". At least this is not the case for knowledge that surpasses the limits of the one explicitly present in the quality management system. For the laboratories studied, the documents resulting from the research process are, in most cases, not managed by these systems. Not even documents presenting final results, usually publications, are always included in these systems. This is in spite of the importance these documents have as indicators of the performance of the organization[87]. Nevertheless, three laboratories, LIS[88], LECA[89] and CERMAV[90], have included the management of their publications in the QM systems. These publications could be seen as representing the conceptual knowledge assets developed by the organization. Thus, QM could be used to

[87] The number of publications made by the researchers of the organization is one of the indicators used by the CNRS to follow the performance of its laboratories.

[88] Interview report of February 26th, 2003.

[89] Interview report of April 7th, 2003.

[90] Interview report of May 19th, 2003.

improve the management of these assets as a way to supporting the effectiveness of the research activities.

The actual information systems aim at facilitating the completion of activities by providing a tool that makes it possible to find documents or information and to organize those produced. The principle of re-utilization is implicitly present, but not explicitly expressed. In other words, the systems are developed in order to organize more than to re-use.

However, there are elements that could possibly help the management of knowledge. An example is the implementation of an EDM system for controlling all the documentation of the applied research projects at the LCMI[91] and at the SERAS. This system allows keeping control of the advancement of each project and easily accessing previous stages if needed. However, these systems are not used for basic research projects, which continue to lean on the mechanisms defined by each research team.

3.4 Conclusions

As we have shown, we are confronted with a situation where quality management starts to introduce some elements, such as formalization of know-how, document management and sharing of important data, that could support the introduction of knowledge management in research organizations. One example is the documentation process we have discussed. Another one is the use of information systems to manage the documentation produced. However, the observed cases of implementation of QM do not consider KM practices in an explicit way. Nevertheless, this implementation involves the sharing and elucidation of part of the knowledge held by the members of the organization, which is usually part of the objectives of KM programs.

In addition, an important aspect of KM programs is the construction and maintenance of the organizational memory in order to improve the effectiveness of the organization (Stein, 1995). We have seen that for the research activities, both internal and external memories are

[91] The implementation was done for the Installation de production de *Champs Magnétiques Intenses Et Instrumentation Associée* (Unit of production of intense magnetic fields and associated instrumentation). The units in charge of basic research where not included in the implementation of the quality management system.

important. However, only some initiatives have been implemented in order to address punctual aspects related to these memories.

Furthermore, the aspect of project memory, which should be fundamental for research organizations, has only been partially addressed by organizations using QM for technical or applied research activities. Correspondingly, the use of information systems supporting the implementation of QM focus mainly on the support activities and little on the management of the knowledge and information used and produced from basic research activities.

Thus, we have verified the existence of a relation among the implementation of QM and the management of knowledge in research organizations. However, the subject of KM is not explicitly treated. Furthermore, the actions implemented do not address, in most cases, basic research activities. Nevertheless, we believe that it is possible to implement practices that allow generated knowledge to be located, preserved, shared and brought up to date (Grundstein, 2002) for the benefit of the research activity. For that reason, it is necessary to establish a way of complementing the practices already in place and improving the management of knowledge. The question that remains is how to support basic research activities in their knowledge production process.

Part 2. The Problem

Chapter 4. The Problem

> "Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science."(Bush, V., 1945a).

4.1 Introduction

In the previous chapters, we have presented a general overview of the theories related to three subjects: Science, Quality Management – QM, and Knowledge Management - KM. We have also presented the most important aspects we have observed related to these subjects, according to the fieldwork we have done in some research organizations. These chapters have allowed us to see, in general terms, how scientific reality is, how QM concepts are being applied, and how the implementation of QM tacitly helps in to introduce some KM principles.

In this chapter, we will try to draw on these three subjects in order to concretely position our work and, from there, define the subject of our project. We will start by presenting the initial context of the dissertation. Then, we will position our work within the framework of the literature that presents approaches relating QM and KM. Afterwards; we will deep into the analysis of the research activities in order to finally define the question we want to solve.

4.2 Context of the Dissertation

The context of the dissertation is characterised by four main aspects:

1. The growing awareness of the importance of science for society (Erdelen W., 2004).
2. The current experiences of implementation of quality management systems – QMS in some research laboratories.
3. The publications made by different organizations proposing the implementation of QMS in research organizations.
4. The works on knowledge management published in the literature.

The conjunction of these four aspects is at the origin of our subject. We will hereafter explain the links we perceive among them, which in turn will introduce the positioning of our work.

As we have mentioned, some experiences of implementation of QMS are taking place in several research organizations. In the cases we have observed, they were mostly encouraged by their own needs in terms of organization of their activities. Nonetheless, the way of making this implementation is still not supported by a well established methodology. The result is that, as organizations implement QMS, they simultaneously are obliged to look for and develop methods and tools to help the ongoing implementations. For that reason, most of them have opted for starting by implementing the QMS in the support activities, where industry standard QM methods are adaptable to their own reality. Consequently, the QMS we have observed have concentrated on these activities and only implemented very particular actions related to the basic research activities. This situation contrasts with the claims of the (AFNOR, 2001) about the possibility of answering, for the research organization as well as for its researchers, the current issues in scientific, economic and financial, societal and environmental terms through the implementation of QMS.

Another issue to take into account is that research organizations aim at producing knowledge through their research activities. It would be therefore expected that QMS in research organizations include means for improving the activities linked to the production of knowledge. However, reality shows that implementing QMS at a research organization, particularly in the research activity, is not obvious. The research activity is composed of elements that are difficult to envision. In some cases even the results cannot be defined from the beginning of a project. The conjunction of this characteristic with the QMS is not at all evident. Traditionally, one of the fundamental principles of the quality management system has been the standardization. It is based on the analysis of the repetitive actions that leads to the improvement of those actions[92]. Nevertheless, this standardization is hard to envision for research activities. What is more, as the process approach[93] recommended by quality management indicates, the idea would be to take into account the whole knowledge

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[92] See ISO 9000: Quality management principles (http://www.iso.org/iso/en/iso9000-14000/iso9000/qmp.html, accessed on May 10th, 2005).

[93] See Chapter 2 Quality Management in Research Organizations

production process. This means accounting for both the inputs and outputs as well as the activities involved in the research process. In the latter, both inputs and outputs include knowledge as one of the more important elements. Consequently, the implementation of QMS in a research organization should pay special attention to the management of knowledge, the one entering and the one resulting from the knowledge production process, which is one of the key processes of these organizations. For this purpose, it is necessary to define the means to capitalize knowledge, to find ways to encourage the personnel to share knowledge, and to define suitable means to transmit knowledge.

On the other hand, there have been many research works on the way to manage knowledge within companies[94]. Some of the topics involved in these works involve: methods for capitalizing technical knowledge, methods for capitalizing the employees' expertise, methods for building organizational and project memories, and software tools to help manage knowledge. However, the needs of research organizations, related to the management of knowledge, seem to be the object of much less attention in spite of their importance.

Thus, our research started by analysing whether or not the implementation of QMS in research organizations, resulted in the implementation of measures aimed at improving the management of the scientific knowledge used and produced from the basic research activity. Specifically, we wanted to know if when applying QM to basic research activities, the resulting scheme led to the implicit or explicit use of KM methodologies in order to improve the knowledge production process. This would mean, and this was our first hypothesis, that in order to apply QM to basic research activities, it was necessary to use KM techniques, resulting in an approach that combines both methodologies. Interestingly, when looking into the literature, it is possible to rapidly realize that there already exist works aiming at presenting a joint approach between QM and KM. Thus, the next section shows some of them. The brief analysis of these approaches can help us position our work regarding the orientation we want to follow.

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[94] See Chapter 3 Knowledge Management in Research Organizations.

4.3 The Positioning of the Project among the Works Addressing QM and KM Jointly

The idea of trying to address both QM and KM jointly is not new. Several authors have worked on joint approaches addressing both methodologies. For that reason, we propose a typology of the different approaches we have found. It intends to facilitate the comprehension of the existing approaches and not to strictly separate them.

4.3.1 A Typology of Works Addressing QM and KM Jointly

We have found several works that could be grouped in four types:

1. Those that propose approaches integrating QM and KM
2. Those that apply QM and show how QM supports KM
3. Those that use KM to improve the results obtained from QM
4. Those that apply KM and claim that the use of QM can help achieving better results.

In the first group, that propose approaches integrating QM and KM, we find authors like (Zhao, F., 2001), who suggests a framework where KM concepts and Total Quality Management (TQM) concepts are used together in order to obtain an "Integrated Approach to Management" aimed at achieving organizational excellence. Also, (Rodríguez-Ortiz, R., 2003a) proposes a model that combines QM and KM and applies it to research and development processes.

In the second group, that applies QM and show how QM supports KM, we find works such as the one of (Johannsen, C. G., 2000) who claims that the basic quality control tools support organizational knowledge creation and transfer. Additionally, (McAdam, R., 2004) claims that critical TQM culture programmes can be used to develop knowledge creation. In addition, (Linderman, K., et al., 2004) propose an integrated view of quality and knowledge using Nonaka's theory of knowledge creation. Similarly, (Bénézech, D., et al., 2001) claim that the ISO 9000 series can contribute to the conversion of knowledge, referring to the knowledge conversion cycle proposed by (Nonaka and Takeuchi, 1995). This was later verified by (Molina, L. M., et al., 2004) who show the influence that the certification, according to the standard ISO 9000, has on knowledge transferability and the importance of TQM on the degree to which the firm transfers knowledge.

In the third group, that uses KM to improve the results obtained from QM, we encounter works like the one of (Galendere-Zile, I., et al., 2002). They propose the implementation of a KM system for QM that consists of two main components: knowledge contents and architecture concerning QM and KM tools for QM. However, this system is only described in a very general way, without specifying how it could be concretely implemented and used.

In the fourth group, that applies KM and claims that the use of QM can help to achieve better results, we find works such as the one of (Tsai, B., 2003). He proposes a "total quality knowledge management system" that supports the construction of information maps, which allows the exploration and recognition of important scholars in a particular field by using citation data mining and information landscaping techniques. Also, (Pfeifer, T. et al., 2000) propose the utilization of QM techniques for "ensuring the availability of the appropriate knowledge".

We have seen four kinds of works looking at both QM and KM. Some of them are mostly theoretical, while others present specific applications. For us, their value rests on the exploration of the different ways in which these two methodologies could be linked, encouraging us to explore how they could be linked in the specific context of research organizations. In the next section, we will define our position regarding this classification.

4.3.2 The Positioning of our Project Regarding QM and KM

We will now use the typology presented in the previous section to position our work. As we have said, our interest is the basic research activity as an activity that produce scientific knowledge. Thus, our hypothesis was that QM, when applied to these activities, would require KM. Consequently, at the beginning of our work, we positioned ourselves in the first group, as our hypothesis implied having an approach joining QM and KM in order to apply QM to an activity based mainly on the management of knowledge. Nonetheless, the observation of some experiences of implementation of QM in research organizations, have not allowed us to see such an approach. Furthermore, the implementation has focused mainly on support activities, and has only been used, by some organizations, for very specific aspects related to the research activity such as the organization of sources of data used by researchers, or the organization of laboratory publications. Consequently, the observation work has allowed us to verify relations between QM and KM, by showing how the implementation of QM involves the elucidation and sharing of knowledge. In this case, organizational knowledge related to the know-how concerning the support activities. Then, this work could be classified under the second group.

Nonetheless, the verification of the relationship between QM and KM does not provide much of an answer to the question of how to improve the research activities. A possibility is to use KM methodologies to manage the dynamic aspects of the research process, and to use QM methodologies for organizing the stable aspects[95]. The experiences we observed, show us that it is possible to use QM for aspects such as the establishment of laboratory protocols; the implementation of databanks; the definition of means to keep the information about the publications made by the laboratory; and the management of technical instruments. This shows us that QM can indeed be used for structuring some aspects of the research activity. The question is whether or not KM can also be used for improving the dynamic aspects of the research activity and to define, concretely, how to do it. This work could be then positioned within the third group, since the KM methodologies would complement the aspects addressed by the QM system in order to obtain better results. Then, the question we will attempt to answer is:

> *How could the KM methods be used for improving the development of the research activities in a way that complements the aspects already covered by the QM systems implemented in the research organizations?*

In the next section, we will describe the concrete aspects we will aim to consider in order to treat this question.

[95] We note that the works belonging to the field of research methodology do not form part of the scope of this work. What we have intended to do is to see if managerial initiatives such as QM and KM can be used to improve research activities.

4.4 An Approach for Addressing Knowledge Management in Research Activities

The application of KM to research activities could focus on very diverse aspects. However, since this activity is mostly structured in research projects, we consider the project to be the main aspect to be addressed. From this perspective, the use of KM methodologies should aim at supporting the researchers in their activity and at capitalizing the knowledge they produce through the projects they carry out. Nonetheless, the nature of the research activity implies constantly addressing new questions and therefore developing projects structured according to the specific needs of the phenomenon studied. Thus, given that science is a cumulative process[96], it is desirable to define what means could be used to capitalize the knowledge acquired and developed through the realization of basic research projects. Nevertheless, there are several types of knowledge intervening during the realization of this kind of projects. These types of knowledge involve: organizational knowledge, technical knowledge, analytical competences, specific scientific knowledge, among others. The approach to be possibly used in order to capitalize each type will probably vary. It is thus necessary to define what will be the aspect we want to address. This is what we present in the next section.

4.4.1 Which knowledge to manage?

Given the support that information offers to the management of knowledge, we analyzed in detail the information used and generated during the completion of the different stages of a research project. The analyzed aspects were: basic information required for developing each stage (available means, information on the scientific network, and so on), needs in terms of scientific knowledge, management of publications, know-how related to the dissemination of results, management of instruments, aspects related to the management of the projects, management of competences, support to researchers in their individual activities (management of personal notes, communications, documents, etc.) and strategic aspects that could potentially affect the development of projects (such as the research fields defined as priority). We made the analysis through a matrix where the relationships between these

[96] See Chapter 1 Science, section 1.2.1.1 Some characteristics of the scientific activity.

aspects and the different stages where presented[97]. As a result, we could identify the aspects where the interactions between information and a particular stage were more important. Though important interactions were detected in aspects related to the management of the project, notably regarding the planning of means for the realization of projects, we decided not to focus on this aspect given our interest in research organizations as producers of scientific knowledge.

We noted that most of the knowledge resulting from research projects is already capitalized thanks to the existing dissemination mechanisms existing in scientific research. However, a great amount of the knowledge produced during the research process remains barely capitalized. Therefore, the question is how to manage this knowledge in order to take advantage of it. Here, an important aspect to take into account is the high turnover observed in research laboratories. Consequently, in order to improve the management of knowledge, rather than relying on personnel, it is necessary to rely mostly on the tangible elements resulting from the activity. These elements are constantly produced during the research activity. In fact, according to (Vinck, D., 1995), "a great part of the scientific work consists in producing traces and inscriptions of all kinds... and from them, to produce new inscriptions... The production, the circulation and the handling of the inscriptions are at the heart of knowledge progress system. The work on the inscriptions is a central activity of any scientific practice." Some of these inscriptions serve to keep the trace of the data gathered and treated; others are related to the analysis done by the researchers and vary from informal notes to advancement reports. These correspond to the concept of artifact[98]. As we have said, artifacts are material (or virtual) elements aimed at conveying knowledge. They are ways of translating a part of their authors' knowledge in order to give a representation that can be stored and potentially shared and re-used. For this reason, we decided to focus on the management of artifacts as a way to introduce knowledge management practices into research.

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[97] The size of the resulting matrix does not allow its presentation.

[98] See Chapter Knowledge Management in Research Organizations

4.4.2 What are the artifacts produced?

In order to understand the knowledge production process, we consider it pertinent to remind that cognition occurs in a distributed manner (Hutchins, E., 1999) where people and artifacts instantiate the different states of an organization's memory belonging to a single system in which the work is done (Ackerman, M. S., Halverson, Ch., 2004). In addition, to identify how a system works it is necessary to brake it down into smaller units of analysis to allow the identification of informational inputs and outputs (Ackerman, M. S., Halverson, Ch., 2004). Thus, in order to analyse research projects, we will break them down as a way of defining the artifacts used and produced during their completion. Since the SADT (Structured Analysis Design Technique) modelling technique is based on the decomposition of a system in increasing levels of detail, we decided to use its principles as the basis for modelling research projects (see Figure 4).

We added some additional formalisms that allow us to differentiate, regarding the activities performed, between routine activities, semi-routine activities and intellectual activities and, regarding the outcomes obtained, among main results, secondary results and un-used documents.

In Figure 4, we present only the first two levels of the model (in order to allow its visibility)[99]. The first level (level A) shows that the model represents the knowledge production process in research organisations. Since this process is mostly accomplished through research projects, the second level (level A0) represents research projects. It shows two main aspects:

- The non-linearity of research projects, since researchers are frequently obliged to go back to previous phases of the project. This shows that even the precise definition of the purpose of the project is achieved at the same time the project is realized.
- The existence of routine and semi-routine activities, even though research projects as a whole are non repetitive. This is very important for our purpose, because we can expect to be able to introduce practices or tools offering some support to routine and semi-routine activities (contrary to non-routine activities, where the impossibility to foresee the way in

[99] The complete model can be seen in Annex 8.

which they are going to be developed make difficult the specification of KM methods to support them).

It is important to note that this model is purposely general and not centred on a specific research domain[100]. Its function is to help us define the artifacts produced when developing research projects, more than the exact activities carried out.

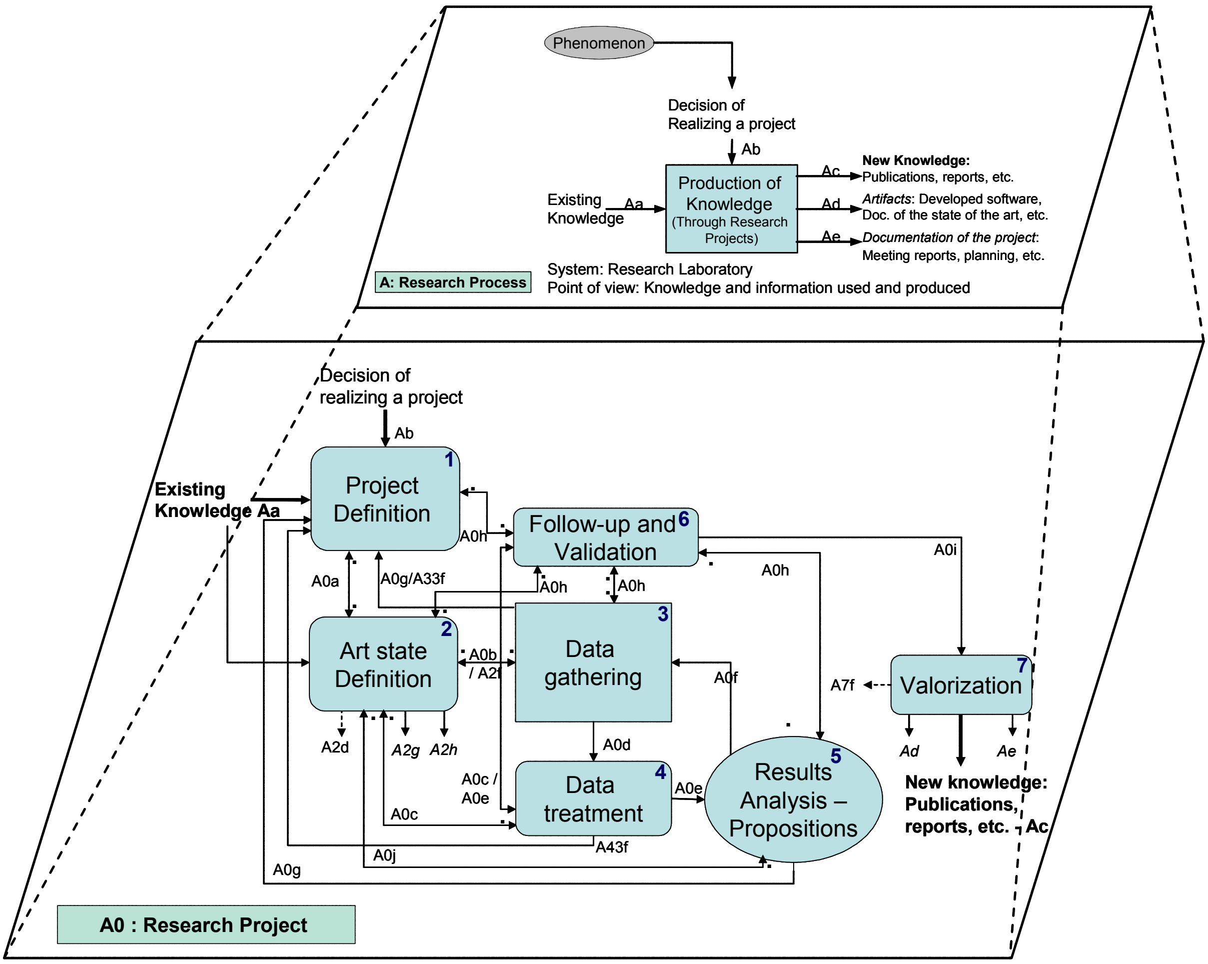

Figure 4. Representation of research projects

Thanks to the model, we were able to identify 102 artifacts (represented in the model as the links between activities) that we, for comprehension purposes, classified into three categories[101]:

[100] However, as we are mostly familiar with research projects made at engineering laboratories, the model is based on observations of this kind of projects. Thus, its validity in other domains should be verified.

[101] The complete list of artifacts can be seen in Annex 9.

- Artifacts related to the bibliography - publications, research reports, books, researchers' notes to documents, concepts found in documents, information on available sources, etc.
- Artifacts related to the management of the project and organizational aspects - project plan, meeting reports, information on available means, etc.
- Artifacts related to the intermediate results - software and hardware developed for a project, data gathered and treated, rejected proposals, etc.

This leaves us with the problem of finding ways to manage these three kinds of artifacts.

4.4.3 How to manage artifacts?

In order to answer this question, we envisioned two possibilities: Methodological tools and Software tools.

Regarding the methodological tools, we analyzed the existing methods for building project memories[102]. We have identified many interesting works[103], but none of them adapted to the characteristics of research projects, especially because of the dynamic environment and the non repetitiveness of the projects. That is why we were interested in the possibilities offered by information technology to capitalize artifacts as a mean to make the realization of research projects easier. Thus, the next sections show the KM software tools currently available on the market, the software tools offered to support research organizations and the tools proposed by researchers to support research activities. The purpose is to analyze their functionalities and their capacity to facilitate the capitalization of the artifacts issued from research projects.

4.4.3.1 The existing software tools for knowledge management

We have tried to identify the most important knowledge management software tools currently available on the market in order to analyze their functionalities and their capacity to facilitate the capitalization of the artifacts issued from research projects. For doing so, we used an automated search and web intelligence solution[104] during a two month period (July – August, 2003). This allowed us to identify 53 enterprises, offering 224 KM tools. In order to facilitate

[102] See Chapter Knowledge Management in Research Organizations

[103] See, for example, (Bekhti and Matta, 2003).

[104] The solution used was Google Alert.

the comprehension of the kind of tools we identified, we have classified them according to the main functionalities they offer[105]. The result of this classification is presented in Table 3.

Type of functionality	No.of tools found	Examples of tools
Document Management	38	iManage WorkDocs™, Hummingbird DM
Collaboration, Groupware	29	Hummingbird CollaborationTM
Search Engines	28	Nexidia's NEXminer, Open Text's BRS/Search™
Content Aggregator, Portals	27	IBM's DB2® Information Integrator for Content, Computer Associates' CleverPath Portal
Content Management	17	IBM® DB2® Content
Business Process Management, Workflow	12	IXOS-eCONprocess, Staffware Process Suite, AppianWorkflow
Knowledge Agents	8	Autonomy's Active Knowledge™
Project Management	6	Accelrys' DS ProjectKM, Kinematik's eNovator.
E-Learning	6	LongView's LRALTM, Eedo's ForceTen.
Graphical Visualization, Knowledge Maps Systems	5	IBM's DB2 Intelligent Miner Visualization, Lotus Discovery Server, Inxight's Star Tree™ SDK
Data Integration tools	5	Hummingbird ETL, Newgen's OmniExtract
Document Routing	4	iManage WorkRoute, ISYS:rdu
Text Base	2	Inmagic's DB/TextWorks
Linkage of documents by hypertext	2	Tikit Document Link
Others	35	Open Text's Livelink Review Manager for Acrobat, Serviceware's Cognitive Processor

Table 3. A proposed typology of commercial KM tools

This table presents the type of functionality regrouping some tools, the number of tools found under each one of the functionalities and finally, the names of some examples of tools available on the market. It is important to note, though, that this classification is made only to present a panorama of the kind of support offered on the market and does not aim at being either comprehensive (as it is a very dynamic sector) or strict (as some tools present functionalities belonging to more that only one of the defined types).

This classification shows that the offer is very rich and varied. Even more, these tools offer many possibilities for knowledge management in research organizations, since there exist several tools that could help manage part of the artifacts used and produced during the realization of their activity. This is in spite of being, for the most part, software conceived for

[105] The complete list of identified tools can be seen in Annex 10.

industrial organizations. Consequently, we are inclined to think that it still lacks a tool adapted to the basic research activity, focused on the capitalization of the artifacts resulting exclusively from this activity.

4.4.3.2 The existing software tools for supporting research organizations

We deepened our analysis of the tools available on the market with a search for products conceived for research organizations. We identified 15 enterprises offering 35 tools we considered interesting for supporting KM activities[106]. As we did with the Commercial KM tools, we classified them according to their main functionality. Once again, we note that this classification is made only to present a panorama of the kind of support offered in the market for research organizations. In addition, we did not take into account tools focused on activities specific to a research domain (such as the experimentation techniques). The result of this classification is presented in Table 4.

Thus, we have acknowledged the existence of several tools aimed at supporting different aspects of the research activities. The offer is particularly important for the support of specific research fields (i.e. pharmaceuticals, chemistry), where the market offers tools for supporting experimental and data treatment activities[107]. In addition, we found a rich offer of tools known in the market as LIMS - Laboratory Information Management Systems, which can be defined as computer software used by laboratories for data management from sample registration right through to analysis and reporting stages[108]. Other than this kind of tools, we found a series of tools focused on specific aspects related to the management of references that mainly aim at easing the identification and access to bibliographic sources. Consequently, we observe two main groups of software tools: First, those related to the experimental activities, which include data management, and second, those managing some aspect related to the bibliography. However, in the first group we observe comprehensive solutions, while in the second the offer targets specific activities.

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[106] Annex 11 contains the detailed information about the main identified tools.

[107] Given the specificity of these tools, we did not include them in the table.

Type of functionality	No. of tools found	Examples of tools
Graphical Visualization	2	RefViz, Omniviz
Access of bibliographic sources	6	EndNote, ProCite, Reference Manager, ISI Web of Knowledge, Web of Science, Science Citation Index®
Publication of bibliographic references	1	Reference Web Poster
Search of books in libraries	4	BookWhere, TEXIS, Thunderstone Search Appliance, Webinator
Categorization of documents	1	Texis categorizer
Writing support	2	sciPROOF, WriteNote
Annotation Tool	1	IMarkup Client Tool
Scientific Trends	1	Essential Science Indicators
Information and Data Management	13	CyberLab, OpenLab, E-Notebook, LabManager, Nautilus, Watson, Sapphire™, LVL
Scheduling systems	1	LabCal
Bibliometric Analysis	1	HistCite
Analysis of Documents	2	NVivo, N6

Table 4. Examples of software tools for supporting research organizations

4.4.3.3 The software tools proposed by researchers for managing scientific knowledge

Apart from the tools offered on the market, some researchers have already worked on the development of tools searching the capitalization of knowledge developed through research activities. We have been able to identify some of these efforts, which address some very important aspects of this issue. After analyzing these tools, we have classified them according to the activities they support[109]. Table 5 presents a summary of the tools we have identified, that shows the main activity supported and the field of application for which the tools have been developed[110].

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[108] According to the information provided in: http://en.wikipedia.org/wiki/LIMS and http://www.scimag.com/ShowPR.aspx?PUBCODE=030&ACCT=3000000100&ISSUE=0408&RELTYPE=PR&PRODCODE=00001986&PRODLETT=L&SECTYPE=LIMS

[109] A greater detail about each tool is presented in Annex 12.

[110] In addition to the tools included in the table, (De Jong, H., Rip, A., 1997) present a state of the art regarding "computer-supported discovery environments" where they introduce some tools supporting specific activities in scientific research (i.e. mass spectroscopy). Also, (Simon, H. A., et al., 1997) present some tools for scientific discovery.

Activity Supported	Identified tools	Fields of application
Identification and analysis of citations	CiteBase (Brody, T., 2003)	ArXiv.org Base (mostly Physics),
	ARROW-SMITH (Swanson, D.R., Smalheiser, N.R., 1997)	Biomedical research
	STIS (López-Ortega E., et al., 2004)	Engineering
	DeLIver (Peterson Bishop, A., 1999)	Science and engineering
	Tetralogie[111]	
Modeling of terminology of a Documentary Corpus	Beluga (Turenne, N., Barbier, M., 2004) TermWatch System (Ibekwe-SanJuan F., SanJuan E., 2004) ConcepTool (Meisel, H. and Compatangelo, E., 2002) NeuroNav (Lelu, A., Aubin, S., 2001) Sampler (Jouve, O., 1999) Live Topics[112], NeuroDoc[113], SDoc[114], Tropes[115]	General
Analysis of Documentary Corpus	Porphyry (Bénel A., 2002)	Archaeology
	Prospéro (Chateauraynaud, F., 2003)	Controversies sociology
	ScholOnto (Buckingham Shum, S., et al., 1999)	General
	ANITA (Gardoni M., et al., 2004)	Developed for one Aerospace firm, but applicable in General
	MacWeb (Nanard, J, and Nanard, M., 1995)	General
	WebAnn (Marshall, C. C., Bernheim Brush, A. J., 2004)	Online discussions
Support to organizational knowledge	Epistheme (Oliveira J., 2003)	Agro-meteorology
	Prototype developed by (Tacla, C., 2003)	Research tasks
Discussions	Dito (Angie Voos, et al., 2004)	WWW
	D3E (Buckingham Shum, S., et al., 1999)	Documents
Information repository	ScienceOrganizer	NASA Astrobiology Institute
	NetAcademy (Handschuh, S., et al., 1998)	General
	Knowledge Sharing System (Vorakulpipat C., 2004)	Nectec
Lab Books	Architecture proposed by (Sarini et al., 2004)	Biology
	Smart Tea	Chemistry
	MyTea - MyGrid	Bioinformatics

Table 5. Some tools for managing scientific knowledge

These tools present some very interesting features that take advantage of recent developments of information technologies to support certain aspects of the research activity. However,

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[111] See http://atlas.irit.fr/TETRALOGIE/tetrajeu.htm (accessed on May 11th, 2005).

[112] See: http://mist.univ-paris1.fr/logiciel/tableau/liveto.htm (accessed on May 11th, 2005).

[113] See: http://mist.univ-paris1.fr/logiciel/tableau/sdoc.htm#neurodoc3 (accessed on May 11th, 2005).

[114] See: http://mist.univ-paris1.fr/logiciel/tableau/sdoc.htm#sdoc1 (accessed on May 11th, 2005).

[115] See: http://www.acetic.fr/tropes.htm (accessed on May 11th, 2005).

several of them are still at a development stage or their utilization is restricted to the organization that has developed them. In addition, most of them focus on very specific aspects of the research activity (i.e. identification of complementary literature) or are designed to support specific knowledge domains (i.e. archaeology).

4.4.3.4 An overview of the tools for capitalizing artifacts

In the previous sections, we have presented the tools, either already commercially available or proposed by researchers, which could support the capitalization of artifacts in scientific activities. As we could verify, the offer is very diverse and covers several aspects related to the management of knowledge in general, and to the support of specific aspects of the scientific activities. Concretely speaking, we see that the situation regarding the artifacts we have identified[116] could be schematically presented as follows:

- There are a number of interesting tools offering functionalities for project management,
- there are a few tools offering functionalities for data management, which could support the management of the artifacts related to the intermediate results, concretely those related to the data gathered and treated;
- there are some tools supporting specific research activities such as the support to the writing of documents and tools for specific scientific fields[117];
- finally, some tools manage particular aspects of the management of the bibliography:
    - Search references
    - Visualization of references
    - Management of references
    - Analysis of documents
    - Document Repositories

This allowed us to have a general view of the tools we could count on in order to support the introduction of knowledge management practices in these organizations. Thus, in the next section, we will define the artifacts on which we will focus.

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[116] See section 4.4.2 What are the artifacts produced?

[117] These were not included in the sample.

4.4.4 What artifacts to capitalize?

We had defined the existence of three kinds of artifacts: Artifacts related to the bibliography, Artifacts related to the management of the project and organizational aspects and Artifacts related to the intermediate results. The overview of the existing tools presented in the previous section, shows that while there are tools focused on the comprehensive support to the two last types of artifacts (those related to the management of projects and those related to the intermediate results), the tools supporting the management of artifacts related to the bibliography are focused on certain specific aspects. Furthermore, they do not consider the whole process involved in the manipulation of bibliographic resources. Additionally, they do not take into account the relation between the bibliographical research and the research projects in which researchers participate. According to our observations, the bibliographical research is done to gather knowledge in order to treat a scientific question studied in a project. Thus, the process of bibliographical research includes several aspects. Among them we find: the comprehension of the scientific bases of a knowledge domain, the existing methodologies, the different points of views regarding a same phenomenon, the different approaches that could be possibly used to treat a question, the questionings triggered by the confronted claims, the colleagues working on the same or on related phenomena and even the practical aspects that could support the realization of this kind of research (e.g. which data bases should be consulted when working on a particular domain, which are the main journals and so on). These aspects not only provide a support to the generation of new knowledge in a specific project, but could also be of great utility for future projects. Therefore, they should be capitalized as a part of the project memory of the scientific projects undertaken.

However, the management of these aspects implies difficulties for the researchers that the existing tools do not sufficiently cover. At the same time, this is an activity on which virtually all researchers spend an important part of their time. For this reason, we have decided to concentrate on the capitalization of the bibliographical work done within research projects and, given the advantages information technology offers for this kind of task, to define a software tool for supporting this process. Thus, the question we will aim to answer is:

> *What should be the specifications of a software tool designed both to support researchers and to capitalize the knowledge acquired and produced while carrying out the process of bibliographical research?*

4.5 Conclusions

Our research started with the objective of defining ways of improving the knowledge production process – KPP in research organizations. For this reason, we studied the experiences of some research organizations engaged in QM. Our initial hypothesis was that the implementation of QM should involve measures to improve the KPP. Thus, we observed that this process leads to a series of reflections about the way documents, data and projects are managed, which could be favorable for the introduction of knowledge management practices. However, none of the observed cases formally introduced these practices and, what is more, the implementation of QM in the research activities was rather limited.

Consequently, in order to look for ways of improving these activities, we analyzed the activities performed during the research process and the information used and generated by these activities. This enabled us to observe that a very important aspect in research is the management of the knowledge produced and acquired during the realization of projects. In addition, the literature in sociology of science and our own observations allowed us to see that a part of this knowledge is represented through the great quantity of artifacts produced. Thus, given the high turnover observed in research organizations, we decided to focus on the capitalization of artifacts as a way to capitalize at least a part of the knowledge gathered and produced through research activities.

Subsequently, we had to define which where the artifacts produced. The schematization of the way in which research projects are undertaken allowed us to identify three kinds of artifacts: those related to the bibliography, those related to the management of projects and those related to intermediate results. In order to find ways to capitalize these three kinds of artifacts, we studied two main approaches: methodological tools and software tools.

Regarding methodological tools, we did not find any tool we considered adapted to the bibliographical research activity. Regarding software tools, we assessed the current abundance of options together with the lack of tools that could facilitate the capitalization of knowledge acquired from bibliographical research. Given this situation and the transversal character that this work has relating to different research domains, we decided to work towards the definition of a tool focused on the capitalization of the artifacts produced when carrying out a bibliographical research.

Part 3. The Proposed Solution

Chapter 5. The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research

> "Verbal definitions like Boyle's [definition of an element] have little scientific content when considered by themselves. They are not full logical specifications of meaning (if there are such), but more nearly pedagogic aids. The scientific concepts to which they point gain full significance only when related, within a text or other systematic presentation, to other scientific concepts, to manipulative procedures, and to paradigm applications. It follows that concepts like that of an element can scarcely be invented independent of context. Furthermore, given the context, they rarely require invention because they are already at hand." (Kuhn, T. S., 1996)

5.1 Introduction

In our previous chapter, we concluded that the object of our work would be the definition of the specifications of a software tool designed both to support researchers and to capitalize the knowledge acquired and produced while carrying out the process of bibliographical research done within research projects. The reason is mainly the absence of a tool that allows managing and capitalizing the knowledge acquired through the realization of the bibliographical research done in the framework of research projects. This, together with the fact that this kind of research has a transversal character, since it is present in virtually all research processes at different levels of importance, has convinced us of the importance of working towards the definition of an approach focused on the capitalization of the artifacts produced when carrying out a bibliographical research.

By bibliographical research, we mean all the interactions that a researcher, a project team and even a laboratory as a whole, have with bibliographical sources. That is all the interactions from the moment a researcher (or a research team) starts looking for the available knowledge that could probably be useful for treating a scientific question, to the moment he produces new documents (notably publications), containing his findings (or the findings of a project team). This includes the research, analysis and use of documents, as well as the selection and manipulation of useful concepts until the production of new concepts, usually incorporated in new documents. The idea is to support the researcher in the completion of this work, and by doing so, to capitalize, at least, part of the knowledge acquired and produced.

In this chapter, we present the bases of the specification of an approach that would allow research organizations to capitalize at least part of the knowledge acquired and produced during the bibliographical research done when carrying out scientific projects. These bases are mainly of two types: the implications of the actual practices used by researchers regarding bibliographic artifacts, and some of the KM principles and tools, we think can be useful. Consequently, we start by presenting the implications that the actual researchers' practices have for the design of the tool. This allows us to define the basic elements involved in the management of bibliographic artifacts. Then, we present the principles we think could be used to answer the requirements regarding each one of these elements. We finish by defining the information structure the approach should have in order to support the researchers' activities related to the bibliographic artifacts.

5.2 The implications of the actual scientists' practices regarding the use of bibliographic artifacts

Defining the specifications of an approach, for supporting researchers while carrying out a bibliographic research, requires taking into account the actual practices used by researchers to achieve this activity[118]. These practices show the importance of documents, in general, in the scientific activity. In addition, the related claims verify some of our observations, such as the importance of the documents that remain unpublished, the frequent informal exchanges among researchers referring to formal documents and the importance of the interpretation of formal documents done by researchers. This latter aspect reinforces our position regarding

[118] See Chapter 1 Science.

artifacts, as documents, which we see as a specific kind of artifact, need to be interpreted in order to convey knowledge. Thus, a very important value remains not only in the document *per se*, but also in the interpretation done by researchers, which involves the creation of new artifacts (such as annotations, review reports, etc.).

According to our conception of knowledge[119], this one is precisely contained in the interpretation done, which leads to act upon it. In consequence, an important issue we have to deal with is the capitalization of the interpretations done by researchers while analyzing a document, and not only with the filing and retrieving of documents.

Furthermore, we consider important to take into account that the interpretation is done in the framework of specific projects that give the context of utilisation of the documents. For that reason, we lean on the work we have done for analyzing the interaction between researchers and documents, particularly those related to the bibliographic research. This analysis was done at three stages: The identification, the processing and the use of documents. These stages, together with the capitalization of the bibliographic artifacts, mark the bases of the KM cycle we have defined. For that reason, in the next sections, we will analyze the implications that the practices identified in each one of these stages have for the design of the tool.

5.2.1 The identification

One of the important stages in the bibliographic research process is the identification of possible useful documents. The scientists' practices give us the bases for defining the aspects we should take into account in the design of the approach. Thus, different studies have shown that journal articles, particularly electronic journals, play a fundamental role as information sources in several work fields. (Garfield, E., 2005) even affirms that "for some younger authors if it is not electronic, it does not exist." In addition, it is also important to take into account the use of paper sources (e.g. books and reports). Other important information sources are conferences and the Web, where the PDF format is widely correlated to the

[119] See Chapter 3 Knowledge Management in Research Organizations.

scientific publications. Therefore, the tool should acknowledge at least these sources and bear in mind the prevalence of the PDF format for the electronic documents.

In addition to the recognized usefulness of electronic sources of information (e.g. electronic library subscriptions), the wide use of software for controlling the references used has also been noticed. This shows that, increasingly, documents are obtained through electronic sources and controlled through software. This has two implications: on one hand, the importance of electronic information sources supports our intention of working towards the improvement of the computational support linked to the bibliographic work. On the other hand, the existence of software tools that already fulfil certain functions related to the management of the bibliographic references allow us to concentrate on other aspects[120].

Another important aspect is that the literature sources used by the research organization present specificities that account for the research fields explored and the preferences of its personnel. It is then desirable to support the maintenance and the communication of the selected sources of information that are used at the laboratory level, notably the selected journals. In addition, it has been seen that researchers keep personal collections of selected bibliography. These personal libraries try to gather important documents presenting high utility and value to be used on a regular basis. Therefore, it would be desirable to help researchers build and maintain their libraries by supporting the identification, incorporation and retrieval of valuable articles.

In addition to the electronic sources of information, the utility of identifying knowledgeable people as a source for identifying documents has been noticed. For this reason, it is necessary to allow researchers to locate fellows according to their areas of expertise. This is considered as a very valuable source, because it does not only mobilize information, but represents the real source of the knowledge acquired and developed by fellow scientists.

The next aspect we are going to analyse is the implications the scientists' processing practices may have on the design of the approach. This is the subject of the next section.

[120] See Chapter 4 The Problem, section 4.4.3.2 The existing software tools for supporting research organizations.

5.2.2 The processing of bibliographic information

We have also seen some aspects characterizing this stage. One of them is the increase in the amount of reading per scientist, together with the time-spent reading. In addition, the reading of electronic journals mainly for supporting primary research, and secondly for current awareness has been also noticed. Therefore, it is necessary to help scientists identify the important documents for the field and the phenomena being studied. As laboratories have a well defined research scope, we think it would be useful to take advantage of the work already done in the projects previously developed or being developed at the laboratory. This may help identifying pertinent works and foster exchanges among researchers. Therefore, it is necessary to put the bibliographic work in the related project context and capitalize this work.

Another significant aspect is the utilization of annotations in the processing of texts. These annotations convey information about the interpretation of a document done by a researcher, thus enriching the document. Therefore, capitalizing them may provide important insights about the subject treated in a document or about related aspects. For that reason, we think it would be interesting to have the possibility of sharing the annotations written on a document and being able to identify their author and know its credentials. This may be useful for indicating the authoritativeness of the author of the annotations and foster exchanges among researchers. In addition, according to what we have seen, annotations sometimes relate to a specific project and even to some aspects of a project. Therefore, it would be interesting to relate annotations to the project for which they are intended. The same applies to concepts. We have seen that annotations may also discuss specific concepts presented in a document, which should later be used to compare the different positions found in the literature. Thus, it would also be interesting to be able to indicate if the annotation relates to a concept, and specify which one.

The next aspect we are going to analyse is the implications the scientists' practices, related to the use of documents, may have on the design of the approach. This is the subject of the next section.

5.2.3 The use of bibliographic documents

We have seen that the analysis of documents heavily leans on their annotation. These annotations may be used later for the writing of new texts, by helping bring together information from disparate sources. However, this reaggregation of annotations seems not to be well supported by the actual tools. Therefore, we consider it important to support this process, in order to facilitate the production of new documents. We think that this could be highly facilitated by the definition of the project or concept to which the annotations relates. This would provide a common aspect around which the researcher could reaggregate the annotations.

Another current practice is using accepted text in new documents and citing well-regarded scientists' work. The difficulty is identifying these works, mainly for people new to a research field or studying a phenomenon new to them. Some solutions such as the Science Citation Index® are intended to fulfil this need. Nevertheless, the current researchers' practices show the use of other mechanisms such as asking fellows experienced in the area of interest. That is why it is important facilitating the identification of the related well-regarded works through these additional mechanisms. This way of identifying important works requires experience in the field of interest because the validation is done by the scientific community. Therefore, the fellows' opinions regarding a work may be particularly important. In addition, the use they do of particular documents may also show the acceptability they grant to a document. Thus, facilitating the identification of "well-regarded" works can also be done by leaning on the scientists and not only on the documents by themselves.

Another aspect regarding the use of bibliographic documents is their application for the improvement of experimental design. This shows that these documents may shape the way in which a project is developed. Therefore it is important to know the documents used in a project and the aspects for which they are used. This may help understanding previous projects (as one can see the bases a project used) and contribute to the reaggregation process (as each aspect of a project uses a set of documents to get insights for treating a question).

In addition, an important part of the reaggregation process is the positioning of the new documents written as a result of the research activity within the current literature. It is then necessary to establish links between the works communicated in the literature and the on-going ones in order to show the differences and, hopefully, the advantages of one's own results. It is thus necessary to facilitate the identification of related literature and organize the identified documents in the framework of the on-going projects.

In addition, it has been noted that there is a collaborative dimension in the writing process, where different people participate and scattered artifacts are mobilized. Therefore, it is important to support the collaboration among researchers and facilitating them the access to the resources used in a project.

We have shown how the aspects noted regarding the scientists' practices have implications for the design of the approach. Thus, we have presented these implications regarding each one of the identified stages in the interaction between researchers and documents. Therefore, we are going to look into the theoretical principles and software developments that could be used in order to answer these requirements.

5.3 Some principles for answering to the identified requirements

In the previous sections, we have discussed some implications the current scientists' practices regarding bibliographic research have for the definition of the specifications of the approach. This analysis allows identifying some specific requirements derived from these practices. Though until now we have studied these practices at three stages, the analysis, and our own experience, of the activity of bibliographic research, as it is done, has convinced us of the necessity of taking into account the non-linearity of the task. This means taking into account that it is done on continuous cycles, where, while some documents are being analysed, others are written by the researcher doing a scientific work, who, at the same time, may identify new documents of interest. For that reason, we considered necessary to look at the activity, not only from the point of view of the stages, but also by looking into the elements being handled. Thus, by analysing the researchers' practices, we could identify the main elements handled. In this way, we can define five sets of requirements, according to the object to which they relate[121]. We summarize them hereafter:

Related to documents:

- Recognizing as information sources journals, conferences and Web publications, among others.
- Supporting the definition of lists of preferred sources of information at the laboratory level
- Supporting the identification of important articles older than a year.
- Contributing to the identification of well-regarded works
- Capitalizing literature reviews

Relating to annotations:

- Supporting the annotation of documents at a global level and at a specific level. This means, annotating whole documents or particular passages, allowing signalling important parts of a document and adding the readers' thoughts.
- Supporting the realisation of discussions around annotations
- Allowing the sharing of annotations, keeping the trace of their authors, allowing knowing their credentials and giving to possibility of relating them to specific projects.
- Supporting the maintenance and the research of annotations

Related to individuals:

- Supporting the maintenance of personal libraries
- Keeping updated profiles of scientists

Relating to the developed projects:

- Keeping the trace of the documents used in the framework of a project
- Establishing links between the literature and the experimental design
- Support the definition of the works related to a project.
- Support the collaborative work

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[121] See Chapter 1 Science, section 1.2.3 The use of bibliographical documents in the scientific activity.

Related to the subjects treated:

- Supporting the gathering of information from different sources relating to a same subject.

Thus, we have five elements that represent the basic activities done by researchers regarding bibliography. Responding to the identified requirements aims at facilitating the realization of these activities. Some of these requirements are or could be supported by the existing solutions. Therefore, we are going to look into the theoretical principles and software developments that could be used in order to answer these requirements.

5.3.1 The support to the management of documents

Different types of systems such as electronic document management (EDM) systems or innovation support tools[122] could support the management of documents. However, the specificity of the scientific activity and that of the organization need to be addressed. For that reason, we think that some of the knowledge capitalization methods could be used to elucidate and share aspects such as the main information sources employed. In addition, it is also necessary to support the identification of important articles. For this purpose, we think that the use of documents is an indication of their importance. Thus, it would be necessary to trace the use made by scientists in the framework of the projects they develop.

These aspects, the main sources and the traceability of the use of documents, could contribute to the building of an organizational memory allowing sharing, among the members of a research laboratory, the artifacts used and produced through the work done. From our perspective, this organizational memory might be comprised of two aspects: the organizational memory of the support activities and the organizational memory of the research activities. The quality management system addresses the first aspect by supporting the elucidation of the basic aspects relating to the main support processes of the organization, while the KM should specify ways of addressing the second aspect. Thus, aspects such as the main journals, conferences and Web sites could be treated as part of the organizational memory of the laboratory and therefore managed according to the KM cycle.

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[122] See Chapter 3 Knowledge Management in Research Organizations, section 3.2.8.1 The types of KM Systems.

However, the organizational memory of a research laboratory should include more than just the main sources of information and the trace of the use of the documents identified. Hopefully, this memory should also reflect the work scientists do with these documents, which implies managing the annotations done while using them. This is the subject we will present in the next section.

5.3.2 The management of annotations

Annotations reflect the processing done of the identified documents. These annotations are important artifacts because they enrich the documents and contribute to the development of the other activities that take part of a project. That is why we consider it important to keep them in order to contribute to the organizational memory. Therefore, we could rely on the principles of the existing developments aimed at supporting annotations[123]. Some of the existing developments (e.g. IMarkup Client Tool) focus on annotating Web pages, which is not our case. However, the principle is to help users remember and share their annotations.

Thus, after analysing these developments, we found that some of them contain important features for responding the requirements we have identified. One of these developments is ANITA, an annotation tool focused on the annotation of PDF documents or parts of them. It recognizes that researchers pay attention to specific aspects in the documents used, which commonly use the PDF format. Another interesting annotation tool is Porphyry 2001. In it, "every annotation is dated and authored, so that it can be interpreted, contradicted by another annotation, or considered as obsolete" (Benel, A., et al., 2002). Also, WebAnn (Marshall, C. C., Bernheim Brush, A. J., 2004) supports the annotation of documents. It has as special feature the possibility of replying someone else's annotation creating threaded conversations regarding specific aspects of a text. In this way, it is possible to discuss specific aspects around each annotation, which is one interesting possibility for enriching a document through the different points of view expressed.

One aspect we have not seen well developed is the definition of the project that encompasses the analysis of the documents a scientist may be doing. Though the ANITA tool allows specifying the "study" for which an annotation is intended, the study itself does not appear as the structure that contextualises the work done. Therefore, we think this aspect should be reinforced in order to improve the coherence between the work done by scientists and the support offered by information management tools.

Thus, though there already are some pertinent works for the annotation of documents, we think it still lacks an approach joining them together and complementing them in order to better adapt them to reality. Apart from the aspects mentioned in this section, one fundamental aspect that needs to be addressed is the support to the work of individual scientists, who are the ones that do the work and really held knowledge. For that reason, we will now explore what are the possibilities we could use in order to support them.

5.3.3 The support to individual scientists

The scientists' practices have allowed us identifying mainly two aspects relating the work of individual scientists. The first relates to the capitalization of knowledge through direct exchanges with fellows. The second deals with a more practical aspect, which is the habit scientists have of keeping personal collections of selected documents. For that reason, we will explore each one of these aspects.

5.3.3.1 The identification of knowledgeable people

The identification of knowledgeable people means knowing "who knows what". This, taking into account that scientific knowledge is constantly evolving and so does the knowledge held by people. Thus, a researcher's knowledge may be outdated on some fields and have deepened in others, according to the explored questions. Therefore, it is necessary to account for this evolution, which means aiming at knowing "who knows what at a given moment"

This aspect, accessing knowledge through people, has been approached through systems named "expert finders"[124]. As we are interested in working with documents used for

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[123] See Chapter 4 The Problem.

[124] See Chapter 3 Knowledge Management in Research Organizations, section 3.2.8.1 The types of KM Systems - Knowledge map systems

bibliographic research, we think a suitable approach could be to extend the functionalities we may develop for this purpose, in order to identify knowledgeable people. If we take into account the two approaches proposed by (Hertzum and Pejtersen, 2000)[125], this would mean using documents for identifying people's knowledge. Though (Hertzum and Pejtersen, 2000) refer to the authors of the documents, we think that the utilization of documents can also be used for knowing the areas of interest of a researcher. Thus, the proposition would be to exploit this possibility, in order to allow researchers to identify fellow colleagues with similar interests.

Another aspect to take into account is that research organizations present high turnover levels. Consequently, knowledgeable people leave the organization, often taking with them the artifacts they have identified and created and by this way, preventing others in the organization to profit from potentially useful materials. Therefore, we will preserve the identified and created artifacts.

This aspect, which is the preservation of the identified and created artifacts relates to the different elements involved in the work with bibliographic documents, such as the documents, the annotations, the projects and the subjects treated. Therefore, keeping the trace of the authors of the researcher who identifies, creates or uses an artifact, can help representing his knowledge and establishing if it is possible to directly exchange with him. In addition, this trace can be used by the researcher himself in order to easily access his own artifacts in order to perform his activities. In this sense, a particular aspect that has been identified is the usefulness of maintaining personal libraries of selected documents. Therefore, we will briefly explore this aspect.

[125] We remind that these approaches are: "to extend document retrieval systems by explicitly exploiting the fact that documents tell a lot about the work activities of their authors and thereby provide a rich description of the authors' experiences and competencies" and "to develop models for classifying people's expertise" (without eliciting people's expertise).

5.3.3.2 The maintenance of personal libraries

Though one of the objectives we pursue is the sharing of the bibliographic artifacts, it is also necessary to deal with the work done by individual scientists. Thus, each scientist keeps the documents he considers most useful for his field of work. For that reason, we think that the approach should function as a portal through which the different elements can be accessed. This would allow using features such as the favourites selection functionality offered by the Web navigators.

A variation we think could be introduced would be the choosing of a second list containing the favourite concepts of a researcher. This would allow him to easily access the related artifacts as they are used or produced by his fellow researchers. In addition, this could function as a profile of the researcher, as it shows his areas of interest. This could support the identification of knowledgeable people, directly by identifying the researchers interested in a particular or a related concept.

According to what we have seen, the elements contained in the personal library are repeatedly used across the different activities developed by each scientist. However, these activities are usually done in the framework of projects where other scientists also participate. Therefore, it is also necessary to support the collaborative work done in these projects.

5.3.4 The support to the work done in the framework of projects

According to (Vinck, D., 1995) "the scientific fact only exists because of its network of people, things, knowledge and former facts. It entirely depends on the circumstances of its production." This explains why it is important to establish the link between the bibliographic work done and the on-going projects. For that reason, we consider the concept of project memory suitable for responding to the requirements related to projects. Thus, an important component of the organizational memory of the research activities would be the project memories of the research projects developed. These ones are composed of several aspects, one of them being what we could call the bibliographic memory of the project. This memory should reflect the way researchers use and produce bibliographic artifacts, when doing the bibliographic research linked to a project, which is the one we intend to keep.

The other aspects comprised in the project memory of the research projects would be associated to the artifacts related to the intermediate results (e.g. data) and to the artifacts related to the management of the project. We think their capitalization could be done through some of the tools we have identified.

In addition, part of the desired memory could be built just by using tools such as Tikit Document Link, which allows linking documents and projects, in order to have a view or all the documents in a project. However, the other artifacts should also be taken into account into the project memory. Thus, it would be necessary to identify the people participating in a project and keep also the annotations while analyzing the identified documents and the concepts taken into account in the project. Furthermore, it would be desirable to establish, if possible, for which aspect of a given project (i.e. experimental design) a particular artifact is used.

In this respect, an important aspect to take into account is that, usually, several researchers participate in the development of one research project and, at the same time, one researcher may participate at several projects at the same time. It is then necessary to help the researcher control the work he does for each project in which he participates. In addition, it is necessary to allow several researchers work jointly on a same project. This last aspect belongs to the field of CSCW – Computer Supported Collaborative Work, for which Groupware tools have been developed. Therefore, we do not intend to reproduce them, but we intend to take into account the importance of collaborative work in research work and allow it to take place when doing a bibliographic research.

In addition, the construction of project memories could be used later on to implement approaches such as Case Based Reasoning, in order to identify projects presenting similarities and possibly to enrich on-going projects through the identification of complementary literature, insights from fellow researchers and ways of mobilizing existing concepts. In addition, as the bibliographic memory would be built as researchers do their bibliographic research, it could foster exchanges among researchers working on projects presenting some similarity and not only capitalizing on previous projects.

In addition, during the development of projects several subjects are usually considered. Despite the study of a main phenomenon, several considerations are taken into account. Thus, different subjects are analysed with the support of the bibliographic documents. Therefore, it is necessary to gatherer the available information related to a same subject. This is issue we will explore in the next section.

5.3.5 The gathering of information related to a same subject

According to what we have seen, the scientific activity deals with the modification of scientific concepts, which aim at exploring, explaining, describing, predicting or influencing a phenomenon[126]. For that reason, this gathering of information about a subject could be done through the different positions existing in the literature related to a same concept. In this sense, an interesting tool is MacWeb. It provides “conceptual access to information” (Nanard, J. and, Nanard, M., 1995), which could result very useful for the gathering of information related to a same subject. In fact, we have observed that though in early stages of a bibliographic research the work focuses on individual documents, as the work advances, it becomes increasingly important to focus on concepts.

Thus, it is necessary to manage these concepts, bearing in mind that scientific concepts are constantly evolving. For that reason, we think that it would be necessary to establish a way for building a dynamic ontology that support the management of the concepts and account for their evolution[127]. In addition, it is important to know the points of view of fellow researchers regarding the different approaches proposed by other scholars. For the first aspect, we think we can partially rely on annotations, which, according to what we have seen, partially reflected the points of view of researchers. For the second, identifying the different approaches, it is necessary to identify the documents presenting a researcher’s approach regarding a particular concept.

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[126] See Chapter 1 Science, section The development of new concepts.

[127] See Chapter 3 Knowledge Management in Research Organizations, section 3.2.8.2 Ontology as a support to KM Systems.

However, it is still necessary to establish a structure for the concepts mobilized at the organization. For this purpose, we think we could rely on applications such as ScholOnto (Buckingham Shum, S., et al., 1999; Motta, E., et al., 2000) that support the realization of scientific debates around documents. It has the advantage of addressing the subject of usability and sustainability (Motta, E., et al., 2000) which are very important in the scientific context. Although, it addresses a part of the aspects we would like to address, there exist some aspects that would need to be complemented such as the management of annotations, the support to the identification of knowledgeable people and the definition of the activities in the framework of scientific projects. However, we recognize the possibilities this applications could offer if complemented with the other aspects we have identified.

Thus, we have established, in general terms, how the scientists' practices relating the bibliographic artifacts have important implications for the definition of the specifications of the approach. These have allowed us to identify five central elements to the management of bibliographic artifacts: researchers, documents, annotations, concepts and projects that interact while performing the scientific activity. Therefore, we will now present a model aiming to represent how these elements are related in order to define how they could be organized.

5.4 The information structure for the management of the bibliography

The implications mentioned in the previous sections define ways of managing each one of the five elements we have identified as basic for the management of the bibliography. However, what interests us is to have a support that allows scientists to coordinate these elements. For doing so, several authors propose the use of ontology. It should allow organizing the information of an organization, by defining the structuring and the subject of the information. Our work does not aim the construction of an ontology. However, we define the structure of the information we would like to control by Figure 5.

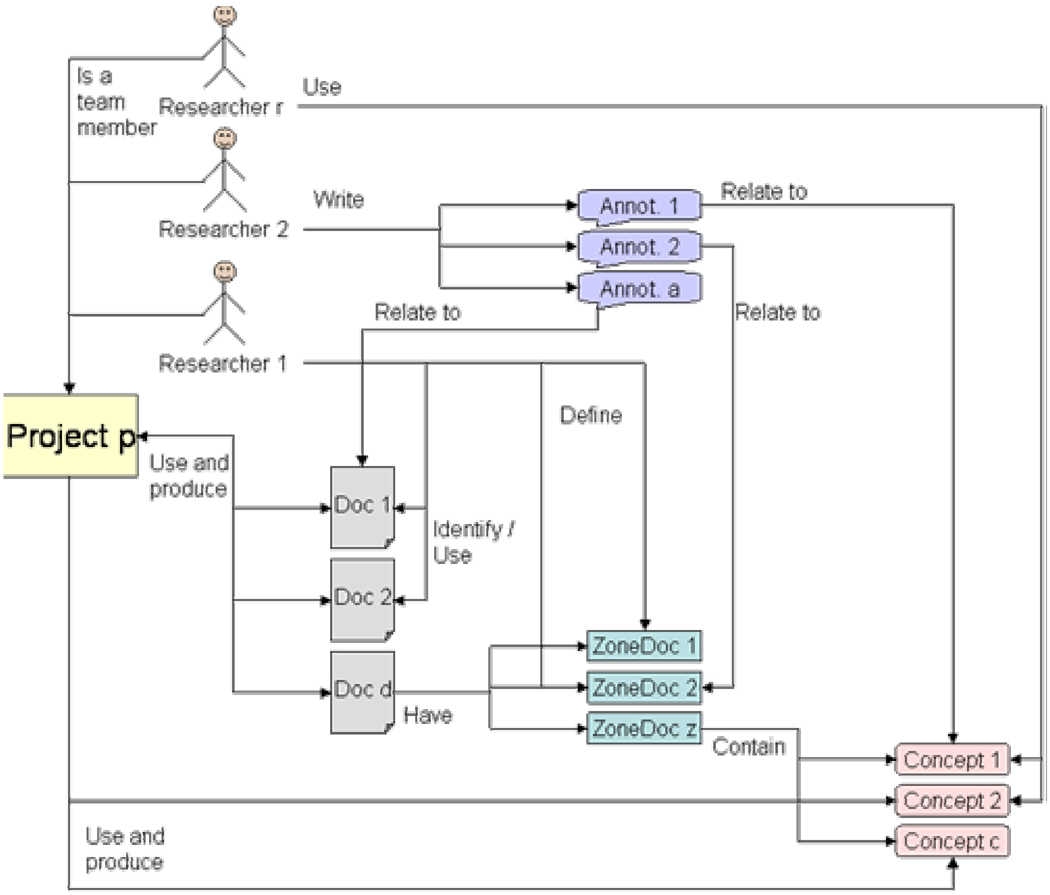

Figure 5. Structure of the information at a project's level

This figure expresses our view of the way the information is present during the realization of a project. In it several researchers participate in the realization of a project. They identify documents potentially useful for analysing a phenomenon. When analysing these documents, they write annotations regarding whole documents or specific zones of a document. The latter may refer to particular concepts that a project could use in the project. Consequently, the annotations can refer also to these concepts. These elements would constitute the bibliographic memory of the project, which as a result may modify existing concepts of develop new ones.

Repeating this process through the different projects a laboratory develops, leads to the identification, the modification and the development of several concepts. Thus, the structuring of these concepts could favour the identification, and by this way the re-utilization of bibliographic artifacts. This structuring could be seen as a domain ontology. However, it would only be a level 1 domain ontology, as we do not aim the concensualization of the different viewpoints that may exist regarding a concept[128]. In fact, we would mostly aim at allowing "redundancy" (Nonaka, I., et al., 2000), as a way of fostering knowledge creation. Thus, for each concept we would aim at the identification of several instances presented in the literature.

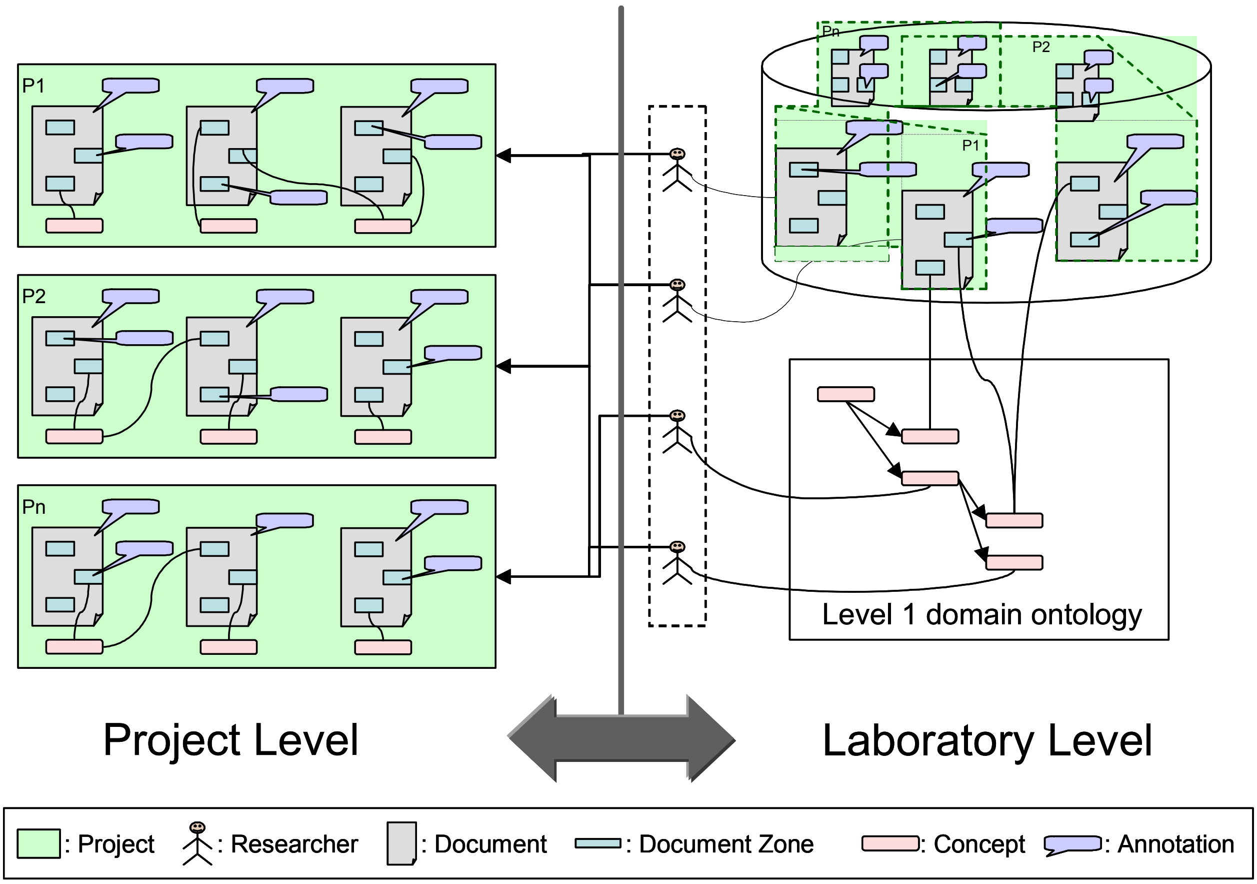

Figure 6. Representation of the information structure

Consequently, at the laboratory level we would share the bibliographic artifacts used through the projects developed in order to capitalize them. Figure 6 provides a schematic representation of the resulting structure.

In this representation, we present the two main levels we will aim to support: the project level where the bibliographic artifacts are used and created, and the laboratory level, that allows sharing and re-using those artifacts. Thus, the artifacts present at the laboratory level could be used by the on-going projects, where additional artifacts would be identified and created. A

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[128] See also (Buckingham Shum, S., et al., 2000)

third level is the individual level, where researchers would keep a personal library based on two elements: His favourite documents and his favourite concepts, that would allow him to access possible new documents identified by other researchers regarding it. Additionally, this concepts list could work as a profile of the researcher because it represents his areas of interest. Thus, it could foster the exchanges among fellows presenting similar interests.

5.5 Conclusions

In this chapter, we have analysed the implications the actual scientists' practices, regarding the use of bibliographic documents, have for the design of the approach. We have analysed them at three stages: identification, processing and use, which correspond to the three stages we have identified in the interaction between researchers and documents. The principle used is to know the actual practices in order to design a tool supporting them.

From these practices we identified the requirements they implied. Thus, we found that these requirements are related to five basic elements to the management of the bibliographic work: documents, annotations, people, projects and subjects. The developments in KM give us some insights we think can be useful for answering the requirements defined in relation to each one of these elements. For that reason, we have explored the possibilities they offer for supporting researchers in their bibliographic research.

In addition, the study of the interactions among the five elements identified has allowed us to define the information structure we would build with the tool. Our intention is to use these aspects as the bases to design an approach for capitalizing the knowledge acquired when doing a bibliographic research. Consequently, the next chapter present the analyses allowing the definition of the specifications of the approach.

Chapter 6. The Design of an Approach for Capitalizing Knowledge through Bibliographical Research

> "Our ineptitude in getting at the record is largely caused by the artificiality of systems of indexing. When data of any sort are placed in storage, they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path. The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature." (Bush V., 1945)

6.1 Introduction

In our previous chapter, we presented the bases of the specification of an approach for capitalizing at least part of the knowledge acquired and produced during the bibliographical research. These bases are the researchers' practices regarding the use of bibliographical artifacts and the KM approaches. They allowed us to define the general structure of the bibliographical artifacts, as we envision it. This structure presents three main levels: the laboratory level, the project level and the individual level. Thus, the specifications of the approach should take into account these three levels by defining ways of organizing the bibliographical artifacts at each one of them. In addition, we identified five basic elements that interact during the bibliographic research. Thus, the approach should also take into account these five elements and reflect their interactions.

The objective is to provide a support to researchers to facilitate their task without having to dramatically change their current practices. Consequently, in this chapter, we will present different analyses aiming at defining the specifications of the tool. Then, based on these analyses, we define the functionalities of the tool. Finally, we present the prototype of the tool.

6.2 The Analyses Carried Out for Defining the Specifications of the Approach

In order to define the specifications of the approach, we carried out mainly three analyses: Functional analysis, Scenario-based analysis and UML Modelling. The functional analysis helps us define the main functions the approach should fulfil. The scenario-based analysis allows specifying the functionalities a user could expect. Finally, the UML Modelling is used to define the elements involved in order to respond to these functions and the ways in which these elements interact. We are now going to present each one of these analyses.

6.2.1 The Functional Analysis

In order to start defining the specifications of the approach, we made a functional analysis that takes into account the three levels defined for the structuring of the bibliographical artifacts (see Figure 7). As we limit the scope of our analysis to the laboratory level, we recognize three actors:

- The researcher performing bibliographical work on an individual basis
- The project team, where the researchers interact and use the bibliographical work in order to produce research results (by using this work together with the other research activities).
- The laboratory as a whole, where the different project teams interact and share the knowledge acquired.

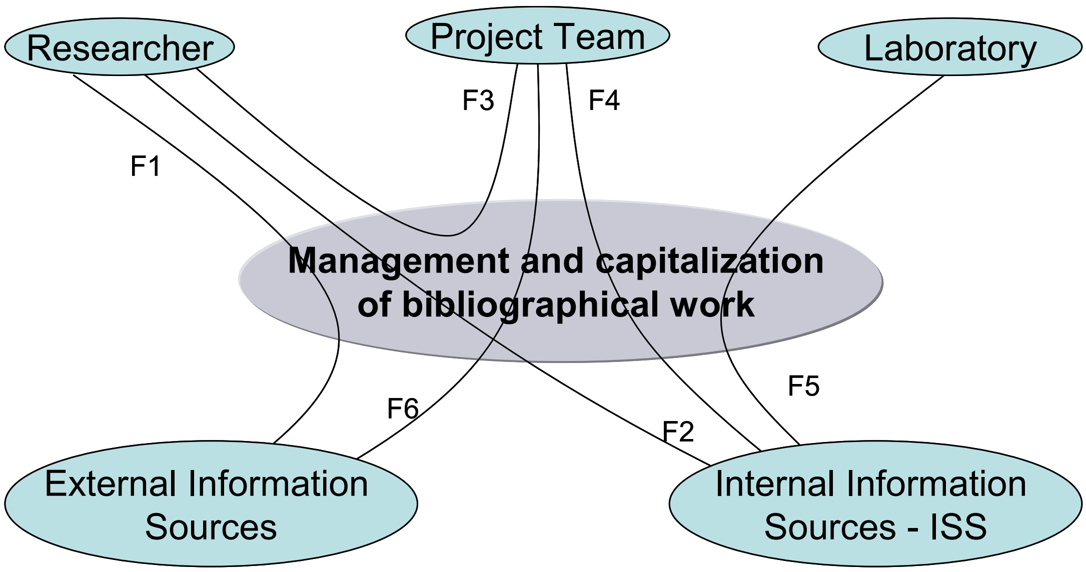

Figure 7. Functional analysis of an approach for managing and capitalizing bibliographical work.

These three actors interact mainly with two entities for doing the bibliographical work:

- The external sources of information that are enriched on a continuous basis with the research results achieved by the research bodies.
- The internal sources of information that should also be continually enriched with the research artifacts identified and created by the project teams inside the laboratory for allowing its sharing. This also includes the updating of the researchers' profiles in order to account for their activities and facilitate the identification of knowledgeable people in specific research fields.

This analysis allows us to have a top-down vision of the bibliographical research. Thus, by analysing the interactions among the three actors and the two levels of information sources, we can define six main functions:

- F1: To locate and analyze interesting information in the external information sources (e.g. Journals, Conferences and Web Publications).
- F2: To choose and to analyze interesting information available in the internal information sources.
- F3: To bring relevant information to a project in progress

- F4: To allow the enrichment of the information available in the internal information sources.
- F5: To share the bibliographical information collected and produced.
- F6: To support the writing of publications (in other words, to support the reaggregation process).

These functions have been declined in a further level of detail, by taking into account the bibliographical artifacts already identified and the current practices used for this kind of research and the uses researchers do of the bibliographical work done. The reason is that we want to support the researcher during all the interaction he or she does with bibliographical sources, from the identification of interesting documents, until the production of new bibliographical material. This implies managing not only the references, as objects, but also the contents they try to transmit. Thus, these functions involve:

F1: To locate and analyze the information of interest. The system must facilitate the activity of search of information and analysis of information found. That means:

- Providing information on the sources of information available (lists of preferred sources)
- Supporting the documents' search process: Control the references found (localization), not found, requested and not received, received.
- Establishing links between the documents found and the research activity: This means allowing the definition of the envisaged use of a document (e.g., a specific project).
- Supporting the processing of documents:
    - Facilitating the location and the extraction of concepts.
    - Allowing adding annotations.
    - Allowing the consultation of the annotations written by other members of the organization.
    - Allowing the expression of one's opinion regarding an annotation.
    - Allowing the qualification of the documents according to their relevance, their reliability, their quality, if they are fundamental for a field, etc. in order to contribute to the identification of well-regarded works.

    - Allowing sorting documents according to various qualification criteria in order to support the definition of the works related to a project.
    - Facilitating the writing of reading logs.
- Facilitating deepening on a concept:
    - Extraction of bibliography.
    - Controlling the concepts to be deepened.
    - Allowing the establishment of links with other concepts related to a concept considered interesting (and with the documents containing it).
    - Informing the researchers interested in the same concept.

F2: Choosing and analyzing the information of interest

- Providing information on the available sources of information.
- Facilitating the access to information:
    - Facilitating the access to electronic documents.
    - Informing the localization of the paper documents.
    - Facilitating information retrieval according to various criteria (for example: field, author, type of document, etc.):
        - Maintaining the information in a structured organization.
        - Providing means for information retrieval.
        - Supporting the maintenance of personal libraries.
- Linking documents to the activity: This means allowing the definition of the envisaged use of a document (for example, a specific project).
- Supporting the processing of documents:
    - Facilitating the location and the extraction of concepts.
    - Allowing adding annotations.
    - Allowing the consultation of the annotations emitted by other members of the organization.
    - Providing information on the other projects, and/or researchers, where a document has been or is used.

- Allowing the qualification of the documents according to their relevance, their reliability, their quality, if they are fundamental for a field, etc.
    - Allowing sorting out the documents according to various qualification criteria in order to support the reaggregation process.
    - Facilitating the writing and consultation of reading logs.
- Facilitating the deepening of the concepts:
    - Extraction of bibliography.
    - Control of concepts to be deepened.
    - Allowing the establishment of links with other concepts related with a concept considered interesting (and with the documents containing it).
    - Informing the researchers interested in the same concept.

F3: Bringing relevant information to a project in progress

- Allowing the definition of the information each researcher wants to share with the other members of a project team:
    - Trace the researchers involved in a project.
    - Trace the artifacts created or identified by each member.
- Allowing the management of several bibliography spaces, according to the different on-going projects.
- Allowing linking a document to the actions envisaged in a project.
- Organizing the information of a project in one same structure.

F4: Allowing the enrichment of the information contained in the internal sources of information:

- Facilitating the transfer of the information of a project to the information contained in the internal sources of information.
- Eliminating obsolete information.

F5: Sharing bibliographical information collected and produced:

- Facilitating the location of the bibliographical information used and produced in the various projects carried out at the laboratory:

- Providing support information for the search for bibliographical information:
  - Presenting a panorama of the available information.
  - Offering information on the documents used in the research projects: List authors of a field, principal works, reviews, conferences, etc, the most used documents the in a field, the most used concepts and information about them.
  - Keeping updated profiles of the scientists of the organization.
- Indicating the last information added.

F6: Supporting the writing of publications:

- Facilitating the location and the extraction of concepts.
- Providing means for finding the documents related to a same concept.
- Facilitating the incorporation of the bibliographical references.
- Facilitating the extraction, and incorporation in a new document, of fragments of documents previously written by, at least, one of the authors of a document:
  - Keeping the trace (information on the origin of a specific part).
  - Facilitating the consultation of the original documents (source documents).
- Facilitating the formatting of documents according to the models established by journals, conferences, workshops, etc.

This analysis allows us to complement the requirements we have defined in the previous chapter regarding the five elements we had identified[129]. Thus, by analysing the scientists' practices, we used a bottom-up approach, which we complemented with the top-down approach used in the functional analysis. This allows us to have a complete vision of the functions required in order to support the bibliographical research. It is now necessary to define how to concretely provide means to implement these functions into the approach.

[129] See Chapter 5. The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research

6.2.1.1 The Support to the Identified Functions

As we saw through the analysis of the existing tools, there already are tools supporting some of the functions identified as being fundamental for managing in a comprehensive way the bibliographic work. However, they only offer a partial support to all the interaction of a researcher with the bibliographical artifacts and there is not a tool offering a support to all the identified functions. In other words, every tool offers some useful functions for the management of the bibliographical work. However, we have not been able to identify a single tool that manages them as a support to the development of research projects.

Moreover, we have not been able to identify any tool that takes into account the management of the scientific concepts that appear in the bibliographical sources. This is a very important function for researchers. Concretely speaking, we were not able to identify solutions concerned with the analysis of definitions and descriptions of concepts contained in different documents. This is an aspect usually done while carrying out a research project[130]. This aspect can be very useful for the research activity in general and for practical aspects like the writing of scientific documents. In fact, according to (Dunbar, K., 1999) "many researchers have noted that an important component of science is the generation of new concepts and modifications of existing concepts. Starting with Bruner, Goodnow, and Austing (1956) many researchers focused on the idea that scientists must formulate new concepts and theories". That is why we intend to support this process by supporting the bibliographical work linked to it. What we intend to do is to overcome the limitations imposed by document management tools that mostly allow only the management of the containers. In fact, what we expect to manage is the contents, as a way of supporting researchers in their activity.

It is important to note that what we intend is to facilitate the process that allows researchers acknowledge the diversity of approaches found in the scientific literature for a same concept. In fact, we have noted that part of the work a research project team has to do is precisely accounting this diversity and defining if one of the identified approaches can be used or if it is necessary to develop a new one. This process allows the team to build the conceptual framework of the project and serves as a support to the other activities carried out during its

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[130] See Chapter 1.Science

realisation. The objective is to share this work with other members of the organization as a way of building a more comprehensible view of the domains in which the organization develops its research. Nonetheless, it is important to mention that we do not intend to build domain ontologies, but quite the contrary, we want to provide researchers a way of acknowledging diversity. This, we have observed, is a very important part of the researchers' work. However, as we have seen, there are other elements involved in the bibliographical research. Therefore, we will now analyse the different scenarios representing the researchers' activities regarding bibliography.

6.2.2 The Scenario-based analysis

For deepening into the detail of the specifications of the approach, we have analyzed the scenarios where it would probably be used. For doing so, we have relied on the study of the activities already done by researchers when doing bibliographical research[131]. For the moment, we have identified eight scenarios. For each one of these scenarios we have identified the possible situations that a researcher can encounter. We have done this analysis for all the scenarios we have identified. The resulting scenarios and situations are:

1. Researcher searching for documents
    - Searches on external sources and/or internal sources (Enters search criteria)
        - Finds documents matching the criteria
        - He does not find documents
            - He may search for projects, researchers, concepts or annotations
            - He may change the search criteria
2. Researcher reading documents:
    - Reads annotations previously done by other researchers
    - Writes annotations:
        - To the document,

[131] See Chapter 5 The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research.

        - To specific document zones,
        - To scientific concepts,
        - To previous annotations,
    - Identifies scientific concepts (may find similarities with other scientific concepts).
3. Researcher writing documents:
    - Uses concepts.
    - Incorporates parts of other documents.
    - Cooperates with other researchers.
    - Formats the document.
4. Researcher searching for concepts.
    - Finds the concept and has access to:
        - documents containing the concept,
        - projects using or having used the concept,
        - researchers using or having used the concept,
        - annotations related to the concept,
        - the related concepts
    - Does not find the concept:
        - He may change the search criteria
        - He may access the complete list of identified concepts
5. Researcher developing concepts:
    - Uses concepts and documents.
6. Researcher searching for projects:
    - Finds the projects matching the search criteria:
        - Finds the concepts and the documents used at different stages of the project,
        - Finds the researchers that participate at its development.
    - Does not find any project responding to the search criteria:
        - He may change the search criteria.
        - He may access the complete list of projects.

7. Researcher participating in projects
    - Identifies scientific concepts and documents useful for the project in general or for specific aspects of it.
8. Researcher searching for other researchers
    - Finds researchers matching the research criterions
    - Does not find researchers:
        - He may change the search criteria.
        - He may access the complete list of researchers.

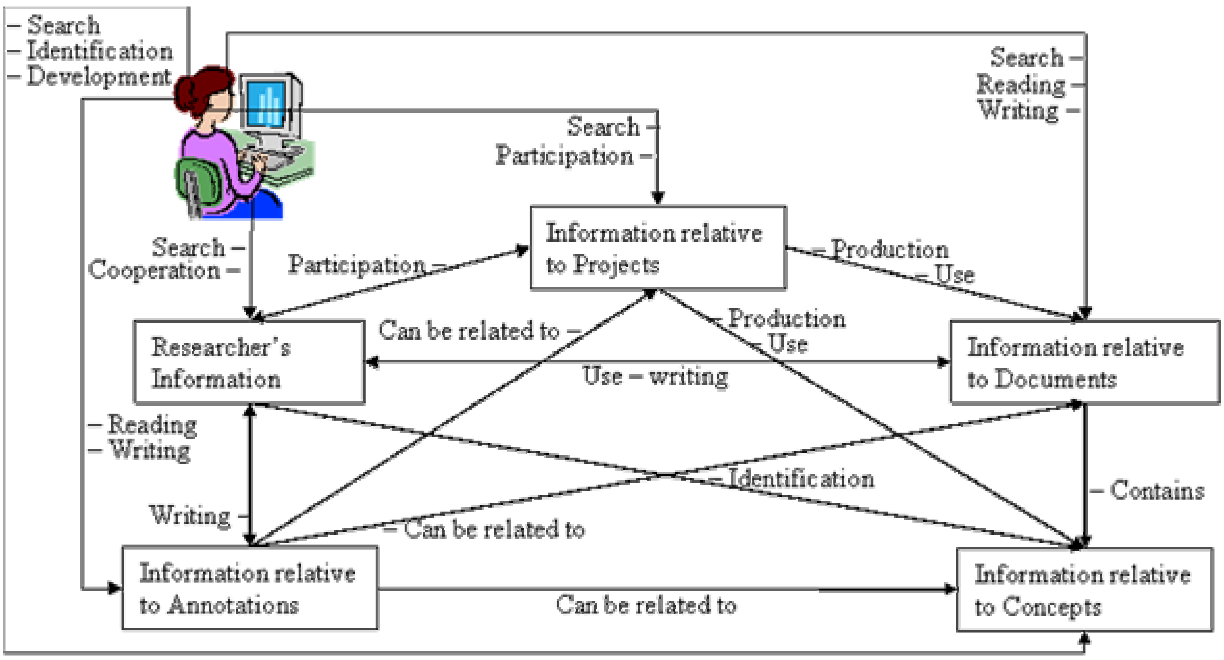

Figure 8. Scenarios of utilization of an approach for supporting bibliographic research

Figure 8 represents these scenarios. This figure shows the different ways in which a researcher could interact with the approach when doing its bibliographical research. We have also represented the relations among the different elements that appear in this activity: Researchers, projects, documents, concepts and annotations. This will serve us as a basis for defining the UML Model of the approach.

6.2.3 The UML Model

In order to find ways for supporting researchers through the realization of the bibliographical work, taking into account the manipulation of scientific concepts, we modelled the system with UML (Unified Modelling Language). What we intend to do is to build a proposition of a functional specification of a system that would accomplish such a task.

We started by identifying the users as follows:

- Individual Researcher: locates the contents containing interesting scientific concepts according to his/her area of research. Additionally, uses concepts for treating the scientific question linked to the projects in which he/she is involved.
- Project Manager: Researcher in charge of the management of the project (may modify the information of the project).
- Visitor: may search the artifacts stocked in the system.
- Administrator: may modify the global structure of the identified concepts.

For each identified user we constructed its corresponding use case diagram[132]. This allowed us to establish the different classes interacting in the system, which correspond to the basic elements manipulated by researchers when doing a bibliographical research[133]. The identified classes are:

- Researcher: represents the categories of user previously described.
- Document: represents the documents that can contain concepts.
- Document zone: represents a zone of a document containing a concept or any information considered interesting for the researcher.
- Concept: represents the description of a concept.
- Annotation: represents an annotation about a document, about a document zone, about a concept, about a project, about another annotation or related to a researcher.
- Project: represents the spaces where the concepts are used in order to produce new concepts.

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[132] See Annex 13.

[133] See Chapter 5The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research, section 5.3 Some principles for answering to the identified requirements

When developing a research project, researchers use these elements identifying, choosing, interiorizing and reconfiguring them according to the phenomenon being studied through a research project. Here, a decision making process takes part. In fact, researchers choose which documents, concepts, and even document zones are going to be used, according to the knowledge of the phenomenon and of the scientific bases they have at a given moment. This process is represented through the some additional elements representing the links among the identified classes. The interactions among these classes are represented in the diagram shown in Figure 9.

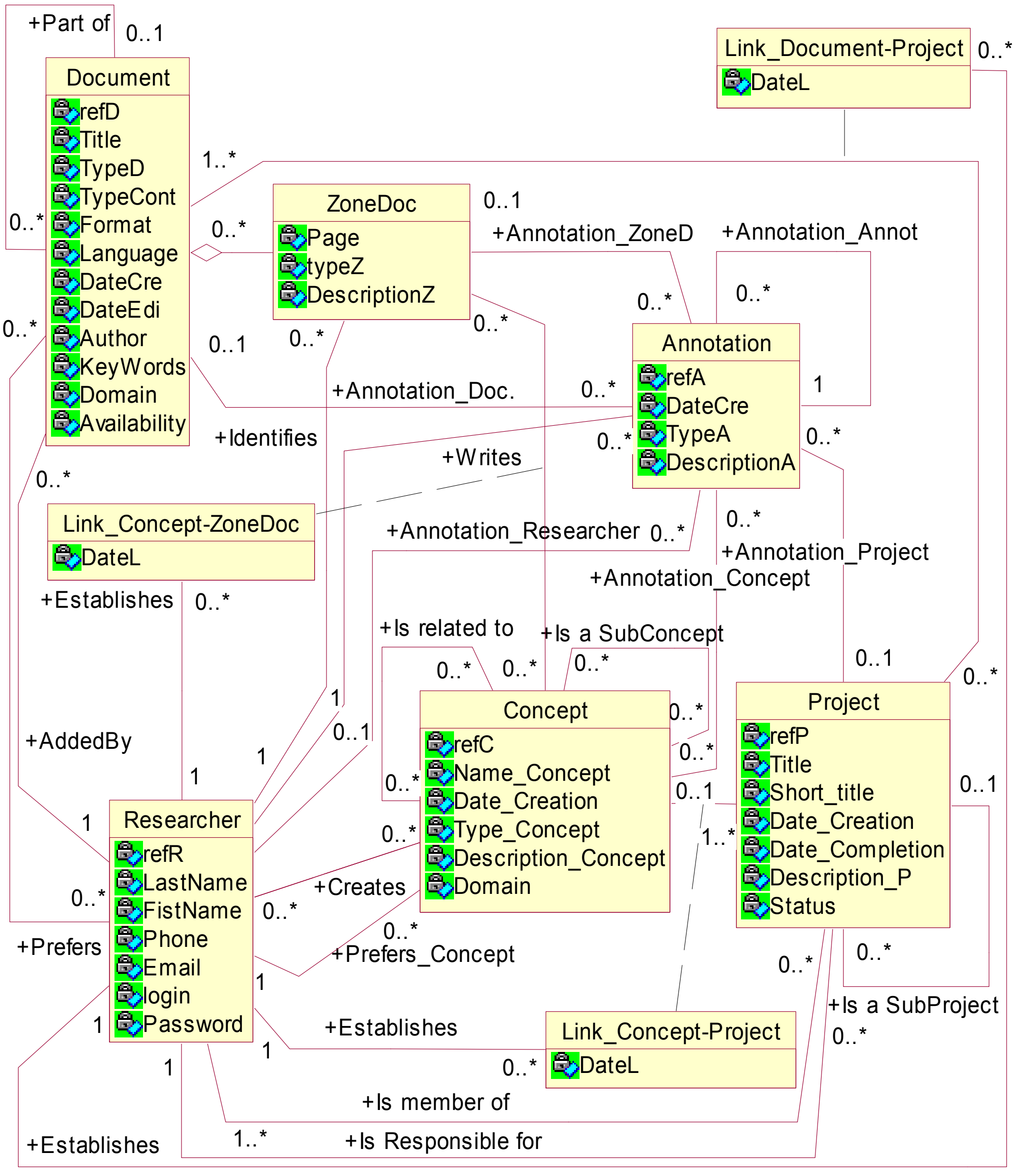

Figure 9. Class Diagram for a support system for the realization of bibliographical work

This model allows us to establish the basis for the specifications of an approach aimed at supporting researchers in their work with bibliographical sources. These are seen as artifacts representing a part of the knowledge produced through the scientific work. Their function is to partially transfer knowledge that other researchers will be able to use to produce new concepts. The idea is to support this process in order to allow researchers to concentrate more on intellectual activities and less on routine activities. In addition, we think that the maintenance of the trace of the work done by a researcher can support the identification of knowledgeable researchers in certain domains.

The analyses we have done, the functional analysis, the scenario-based analysis and the UML modelling, have allowed us to define the main functionalities that the approach should have for supporting the researchers' activities. In the next section, we will present, in greater detail the functionalities of the tool.

6.3 The Functionalities of the Approach

We have started by defining three levels at which the interaction among the identified elements can appear. That is: At an individual researcher level, at a project level, and at the laboratory level as a whole.

What this means is that a researcher may be working by himself or as part or a project and in doing so he may share the result of his own bibliographical research and profit from the one done by his fellow researchers at the organization. This is coherent with the position of (Anell, B., 1998) about the three levels at which learning must occur[134]. At each of these levels, it is necessary to manage documents, concepts and annotations. For supporting the

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[134] According to (Anell, B., 1998), "learninig must occur at at least three levels. The first level is the individual level, the members of the organization must be able and willing to learn and given opportunities to do so… The next level is the group level. It is not enough that individual members are learning in isolation, members of the organization must learn to share new knowledge and use it together in a synergistic way… Learning must also occur on a third level which is, of course, the organizational level. If acquiring and sharing new knowledge do not permeate the whole organization, it will become unbalanced and not be able to use the new knowledge learning has created. The learning at lower levels will not be reflected in the organization's actions."

researcher with these tasks, we have identified the main functionalities he/she would need and we have represented them in a graph-like form (see Figure 10).

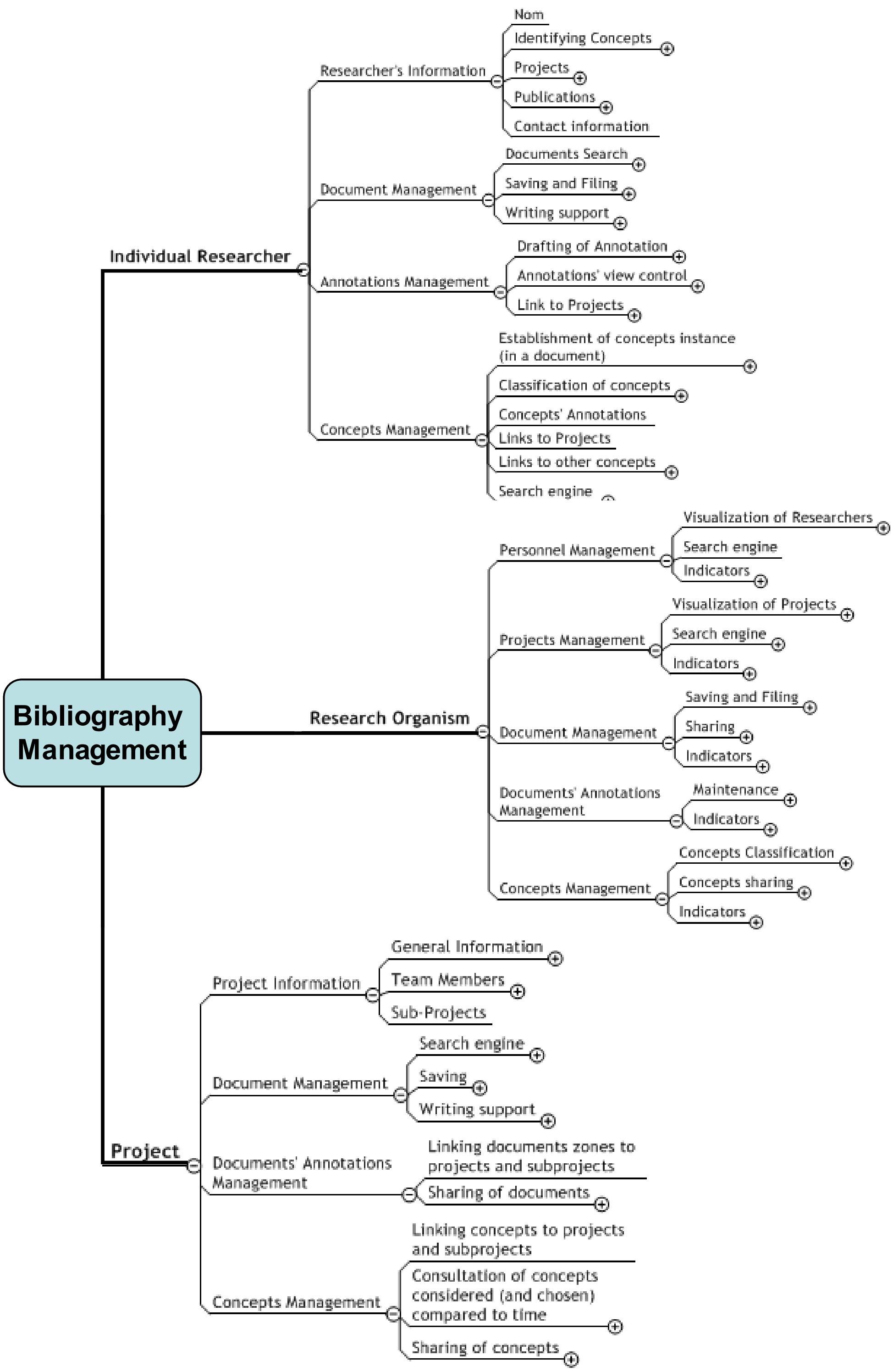

Figure 10. Main functionalities of the approach

These functionalities reflect some basic principles we consider fundamental:

- The approach should support the researcher working individually
- It should support the development of research projects
- It should improve knowledge sharing among all the members of a research organization.

Additionally, there are some essential features. They are: Flexibility, easiness of use, adaptation to the general researchers' practices and maintainability. These features should help us overcome some of the barriers that appear when introducing an approach such as the one we propose.

We have established the main functionalities, features and scenarios of utilization the envisioned approach should have. Together, these aspects form the specifications of the approach we propose for supporting researchers through the bibliographic research. These specifications are the result of an analysis of several studies on the researchers' practices regarding bibliography and of our own observations of these practices. Nevertheless, it is still necessary to verify the approach proposed. This is the subject of our next chapter.

6.4 Conclusions

The analysis of the current researchers' practices regarding the use of documents while performing a bibliographic research, gave us the bases for the definition of the specifications of the approach. Thus, it should take into account that this work is done in the framework of research projects and allow focusing on the scientific concepts used in order to analyse a phenomenon.

For defining the specifications of the approach, we carried out several activities: Functional analysis, Scenario-based analysis and Modelling of the system with UML. Based on these analyses, we have specified the concrete functions the tool should perform in order to support the bibliographic research process done in the framework of research projects. The basic approach implies structuring the bibliographic research process through the establishment of a series of relations among researchers, documents, concepts, annotations and projects, which together set the bases of the conceptual framework of a research initiative.

The next stage is then the development of a prototype, which should serve for demonstrating, in a practical way, the functioning of the approach and the possibilities it could offer to research organizations.

Chapter 7. The Prototype of the Approach: Basic Lab

> "Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, "memex'' will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory… It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing… Thereafter, at any time, when one of these items is in view, the other can be instantly recalled merely by tapping a button below the corresponding code space." (Bush, V., 1945)

7.1 Introduction

In the previous chapter, we have presented the specifications of the approach we propose for managing the bibliographic research process. In order to verify its potential for supporting scientists during this process it is necessary to show the concrete form this proposal could take. For that reason, we have considered it necessary to build a prototype of the approach. Therefore, in this chapter, we show the main technical aspects of the prototype, together with the main functionalities implemented.

In addition, as its purpose is the verification of the approach proposed, we use this prototype to examine the scientists' responses to our proposition. Consequently, we will also present the feedback obtained from the scientists to whom we present the prototype. Finally, by using this feedback we present some possible improvements that should be taken into account for the development of the real tool.

7.2 The Development of the Prototype

The objective we pursue with the development of the prototype of a tool is the demonstration of our approach towards the management of the bibliographical artifacts as a way of capitalizing knowledge. Thus, what we intend is to verify the benefit that such an approach could mean for research organizations, more than the actual development of a software tool. The latter, we think, should only be undertaken once the approach is verified. Therefore, the optimization of the algorithms and the use of state-of-the art computing techniques are not considered at this moment.

In this section, we will present the main technical features of the prototype and a brief description of its functioning.

7.2.1 The Technical Features[135]

At the actual stage, the issues we consider for the development of the prototype are rapidity and easiness of development. Accordingly, one of the basic aspects we define regarding the prototype is that it should function as a Portal. This allows avoiding inconveniences in the installation (as it is done only once), facilitates its maintenance and provides transparency for the users (as the prototype should work through the internet navigator, independently of the actual location of the application and the documents potentially incorporated in it).

Two technologies were candidates for the realization of the prototype: language Java (Servlet, JSP) and the PHP language. PHP is designed to produce dynamic Web pages and interfaces with a large number of Data Base Management Systems – DBMS (Lauer, Ch., 2000). In addition, it has the advantage of being rather simple and rapid to use compared to Java (Orzech, D., Staff, Z., 2001). Additionally, many Web servers, like Apache or IIS (the Web server of Microsoft), support it (Vasudevan, A., 2002). All these reasons led us to choose this language for the implementation of the prototype.

Another aspect to analyze is that a Data Base Management System – DBMS is necessary for the storage of the artifacts handled by the prototype. On the market, one finds several DBMS

[135] The complete details about the development of the prototype are presented in (Amier, F., Aroua, D. M., 2004).

like Oracle, SQL Server, Access, MySQL, among others. MySQL[136] is one of DBMS commonly used for Web applications as it is open source and presents better performance and scalability than other options (Dyck, T., 2002). It proposes important functionalities not offered by other DBMS. It is multi-threaded, which means that it supports the access of multiple users at the same time; supports transactions, which means that it enables data recovery on internal errors, and can be easily integrated with PHP (Amier, F., Aroua, D. M., 2004). In addition, its consumption of memory resources is reasonable and it is easy to manage[137]. For that reason, we decided to build the prototype with a PHP – MYSQL combination, by using EasyPHP[138], which automatically installs and configures a complete workspace. In this way, it is possible to easily implement the support to the databases offered by PHP. In addition, EasyPHP gathers a server Apache, a MySQL database, the PHP language, as well as tools facilitating the development of the prototype. Additionally, we used Macromedia Dreamweaver MX for the development of the portal.

Another important aspect to solve is the management of annotations. For this purpose, we take advantage of the functionalities offered by Adobe Acrobat 5.0 to add annotations to a PDF document (Sohn, W.S., et al., 2003), as PDF is the format commonly used for scholarly documents[139]. In this way, the graphic aspect of the annotation can be managed with the functionalities offered by Acrobat, while their contents are managed through the data base, in order to allow operations such as registry, search, and establish links among the different artifacts contained in the data base.

Summarizing, the prototype is built with a PHP – MYSQL combination, done with EasyPHP, works on a portal built with Macromedia Dreamweaver MX and profits from the annotation

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[136] MySQL: MySQL Reference Manual http://dev.mysql.com/doc/mysql/en/index.html (Accessed on February 1, 2005).

[137] See MySQL Reference Manual : 1.2.2 The Main Features of MySQL (http://dev.mysql.com/doc/mysql/en/features.html)

[138] See http://www.easyphp.org/

[139] See Chapter 5. The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research

functionalities offered by Adobe Acrobat 5.0. In the next section, we briefly present the actual configuration of the prototype.

7.2.2 The Modules and the Functions of Basic Lab

We have partially developed a first version of the prototype. We call it BASIC Lab, which stands for Bibliographical Artifacts for ScIentific Knowledge Creation in Research Laboratories. In it, only the most important functionalities are present, as the objective we pursue is the verification of the specifications defined.

The prototype presents five modules that correspond to the five basic elements we have identified in the bibliographic research[140]. Thus, the five modules are: Document, Concept, Project, Researcher and Annotation. Once a researcher identifies himself, Basic Lab proposes three additional modules: Organize favourites, manage the projects in charge of the researcher and logout. The first of these options should allow him to change the structure of his favourites (documents or concepts), the second should allow him to change the information contained in a project space for which he is responsible and the third option (logout), allows closing a session after having worked with Basic Lab. However, the first two of these additional functionalities have not been implemented yet. Figure 11 shows the first screen of Basic Lab. It allows a researcher to identify himself, access the different modules or start directly by searching a document. This is because we have considered it one of the important functionalities the prototype should include. However, it is important to note that the implementation of the prototype aims only at demonstrating the approach. Thus, the implementation does not intend to reproduce all the options found in existing tools. Consequently, aspects such as the search engine result less powerful that those one can find in tools such as the journal editor's portals. Once again, the purpose is showing how the approach could function and not implementing the actual software tool.

[140] See Chapter 5. The Bases for the Definition of the Specifications of an Approach for Capitalizing Knowledge through Bibliographical Research.

The identification of the researcher using Basic Lab permits the researcher to modify its contents[141], facilitates him the access to his own information and allows the prototype to trace his actions. For this purpose, Basic Lab automatically adds the name of the researcher who creates or modifies an artifact and the date this has been done. This allows a researcher to access his favourite artifacts (documents or concepts), the projects where he participates or enter his personal space and find a log of all the artifacts he has created or chosen as belonging to his favourites lists.

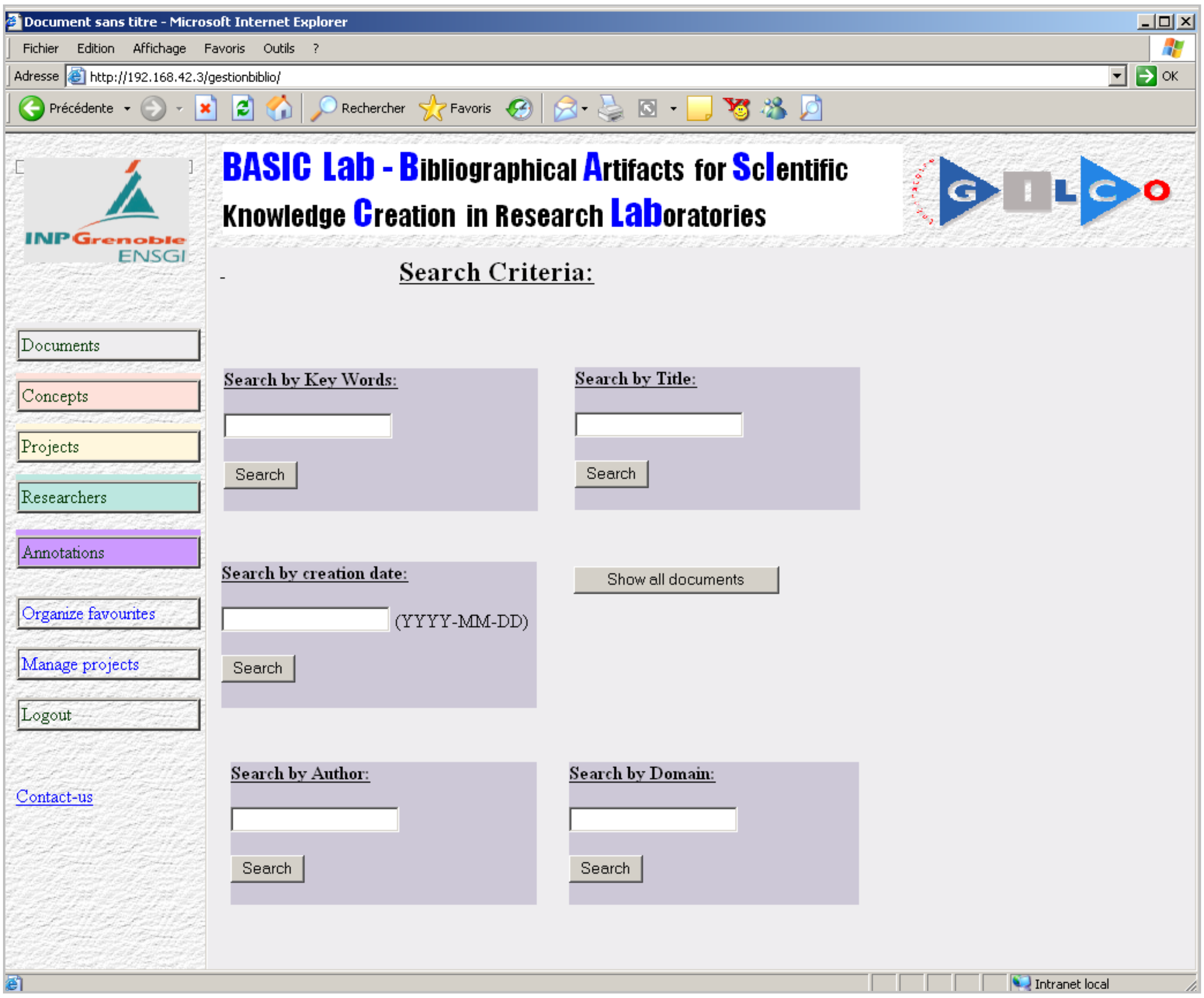

Figure 11. First screen of Basic Lab

In the Document, Concept and Project modules, three basic functions are proposed: Create (a Document, a Concept or a Project), explore the general contents of the prototype (which

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[141] If a researcher does not identify himself, Basic Lab allows him to see the information it contains, but not to modify it.

allows searching Documents, Concepts or Projects) and explore the elements chosen as favourites or the projects in which the researcher participates. In the Researcher and Annotation modules, only two functions are proposed: Search and Show all.

These functions allow searching for information or adding information to the prototype. Regarding the search for information, one of the principles we have kept in mind is facilitating the identification of artifacts through several ways and, at the same time, aiming at identifying as many artifacts as possible. Thus, for example, the prototype allows truncated searches, which makes possible the identification of a higher number of artifacts. In addition, when searching for a particular artifact, Basic Lab presents the information of the search results, together with the information on the artifacts related to the identified possibilities. For example, when searching for a document, the prototype will present a table with the documents responding to the specified criterion, together with the information of the artifacts related to them. Thus, the table contain the following elements: Title, type of document, author, domain, projects where each document is used, concepts previously identified in the document. Figure 12 shows an example of the search results obtained.

Once the researcher has defined the element with which he wants to work (e.g. a specific document, or concept), several additional functions are proposed. In general, two types of functionalities are proposed: Functions modifying the element and Functions allowing accessing other elements related to it. For example, once a researcher has selected a document, the proposed functions are:

- Functions modifying the document:
  - Add document to my favourites,
  - Link document_zone to concept,
  - Link document to project,
  - Write an annotation about this document,
  - Write an annotation about a zone of this document,
  - Show Sub-documents.
- Functions regarding elements related to the document:
  - Researcher: Show researchers who use this document,

- Concept: Explore concepts linked to this document,
- Project: Explore projects linked to this document,
- Annotation: Explore annotations written about this document and Explore annotations written about zones of this document.

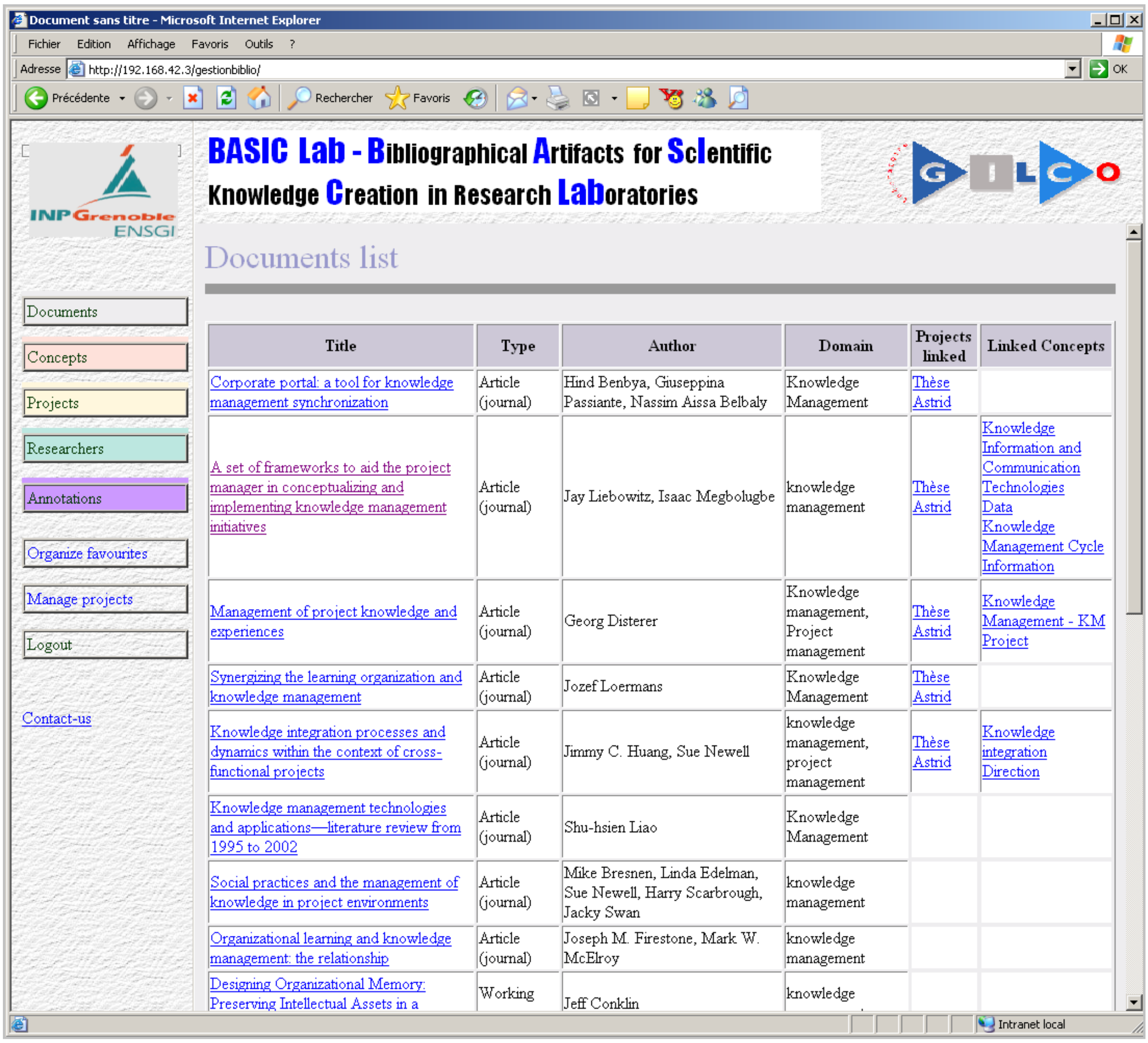

Figure 12. Example of a screen of Basic Lab showing some search results

Additionally, if the digital file of the selected document is available, Basic Lab displays it through an Acrobat® window, which allows using its main functionalities of Acrobat® 5.0.

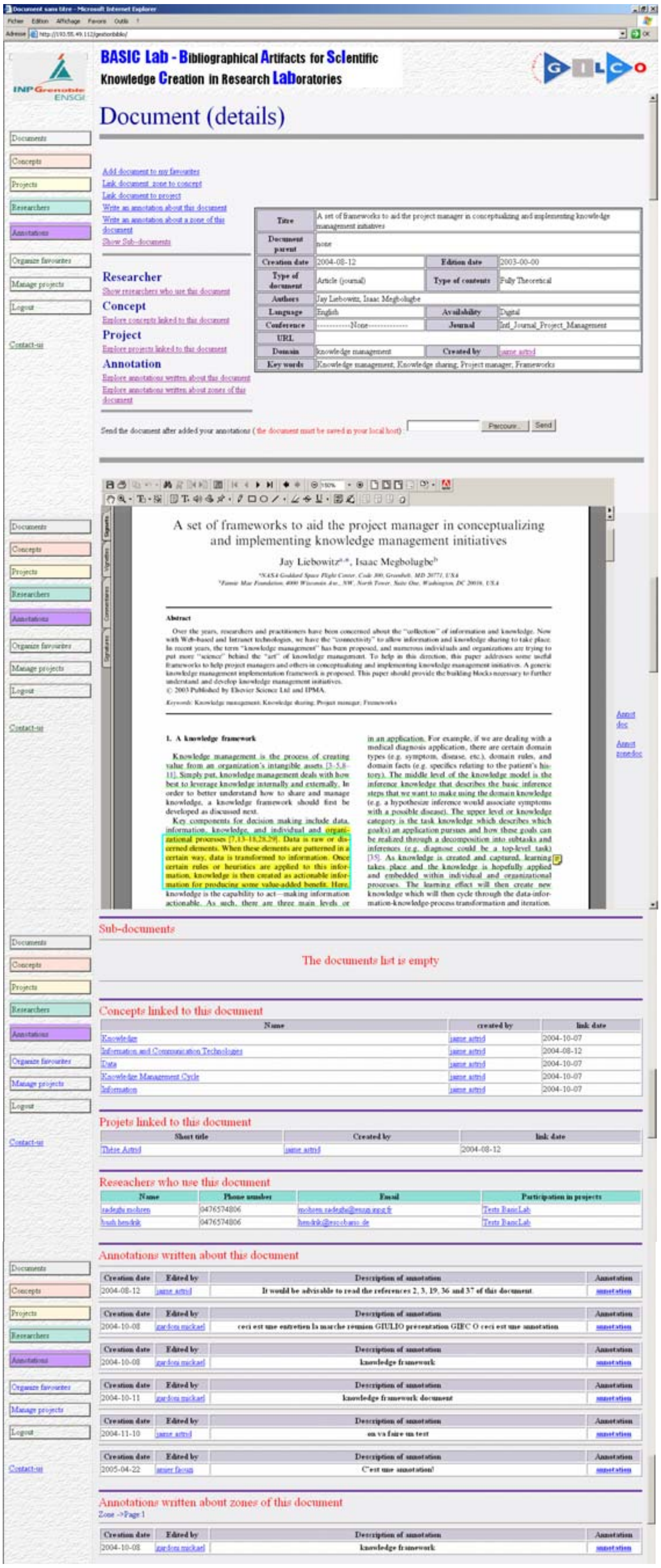

Figure 13. Example of the information provided about a document.

In addition, some information complementing the document is also provided. Thus, the annotations previously written regarding the document or parts of it are shown, the researchers who have selected the document as one of their favourites, the concepts that have been identified in it and the projects where it has been used. Figure 13 shows an example.

These elements aim at enriching the document. In addition, as the elements in the prototype are hyperlinked, it is easy to access the related artifacts (for example, to a particular document) and navigate among the elements present in the prototype. In this way, it is possible to identify further information related to the subject of research and find out, for example, the researchers working on similar subjects.

Additionally, to grant flexibility to the prototype, the elements contained in it present a hierarchical structure where elements and sub-elements can be easily created by the researchers of the organization. In this way, for example, a document can have sub-documents, as a book and its chapters or a standards compendium and the individual standards.

The same principle is applied to projects. Thus, a given project can have sub projects, with different artifacts in each one. In the case of concepts, we also use the same principle. This gives as a result a taxonomy of concepts used in the organization and found in the identified documents.

All these functions aim at supporting the researchers' activities regarding the bibliographical research by supporting the identification, the processing and the use of bibliographical artifacts. In order to better understand how we think the approach can help in this process, we will show in the next section how a researcher can use Basic Lab.

7.2.3 The Utilization of Basic Lab

In order to interact with the prototype, the researcher can identify himself, if he wants to work with it, or just use it to search artifacts (e.g. documents, projects, concepts, annotations and even researchers). In the last case, the researcher can work as an invited to the working space, and can only search artifacts, but is not allowed to realize any actions on them. In this way, the information contained in the prototype can only be modified by the researchers registered in it. The administrator of the prototype is the only one who can do this registration.

If a researcher decides to work with the prototype, he can then use all the functions defined in order to support the bibliographical research process. For that reason, we will try to explain how he can do this at each one of the identified stages[142].

7.2.3.1 The identification of bibliographic artifacts

For the documents, concepts and projects, Basic Lab offers three possibilities to the researcher: Create, Explore or Explore his own artifacts (favourites lists or list of projects). Thus, for example, the user may choose to add a document he has found on the external sources of information to the Data Base (through the "Create a document" option). In this case, Basic Lab will ask him to fill out a form with the main indexing metadata: Title, Edition date, Type of document, Author(s), Type of contents, Key words, Conference, Domains, Journal, URL, Parent Document, Availability, and Language. However, only the title is required for creating a document. In addition, we note that it is possible to envision an improvement in this particular function, by using functionalities such as the ones offered in the tools for the management of references that allow capturing the metadata directly from the editor's portals. Regarding the actual prototype, we remark that the Conference and the Journal tabs include scrolling lists that facilitate signalling the related conference or journal where a document has appeared. Thus, these lists should be collaboratively defined by the members of a laboratory in order to have comprehensive lists. This work demands a stage of adaptation of the approach to the particularities of each laboratory. On the other side, these lists by themselves can be very valuable for new researchers (such as graduate students) as they consolidate information that can be scattered in the organization or present in specific locations, but unknown to newcomers.

In addition to this information, when creating a new document, the user has the option of uploading the file of the document in PDF format[143]. This allows integrating it to the prototype so the researcher can work with it, save it for later retrieval or share it with fellows.

7.2.3.2 The processing of bibliographic artifacts

If the researcher chooses to work with the document he has created, he may access it and work with it. He may then read the document, add graphical annotations, such as underline or highlight a fragment, or add notes to the document or to zones of it. In this case, he must indicate the number of the page to which the annotation refers. He can also indicate the concept, project and researchers related to the annotation. This aims at facilitating the reaggregation process, as the annotations can be later retrieved by accessing the related concept, project or document. Regarding the researcher, indicating a researcher related to an annotation will add the annotation to his personal space. In this way, a researcher may indicate to one of his fellows an artifact that may be of interest to him, thus fostering knowledge exchanges. The annotation itself corresponds to a free text window, where the researcher can insert his own thoughts. The annotations written by a researcher can later be retrieved through the personal space of his author, where all his annotations will be gathered, or be searched through the annotations module.

In addition, a researcher working on a document may choose to link a zone of the document to a concept. This will indicate that the document includes information about a concept. Thus, when the researcher chooses the "Link document_zone to concept" option, Basic Lab presents him a window where he must key in the number of the page where the instance of the concept appears. In addition, he may add a note about this particular instance of the concept. Basic Lab also presents a list of the concepts that have already been created, from where he must choose the concept(s) to link to a zone of the document. If the concept he has identified in the document has not been already created, he may create it by using the "Create concept" option in the Concepts module. If he chooses this option, a new window is presented to him. In it, he can provide the name of the concept he wants to create, donate a description, precise the domain(s) from which the concept is issued, specify the type of concept (e.g. Definition, Methodology and so on) and, if necessary, define a parent concept. This allows creating the hierarchical structure of concepts used at the organization. In this way, one can, for example,

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[142] See Chapter 1. Science, section 1.2.3 The use of bibliographical documents in the scientific activity.

[143] The legal aspects related to the copyrights have not been taken into account for the moment. However, this aspect should be cautiously studied if the tool were to be developed.

specify the knowledge typologies found in the literature. In this case, it would be possible to create the concept knowledge and the types of knowledge as sub-concepts. Thus, when creating a concept corresponding to a type of knowledge, one would specify the concept "knowledge" as the parent concept.

Once he has created the concept, any instances of it may be easily signalled by using the "Link document_zone to concept" option. Thus, if the researcher wants to continue working on the document he had selected, he can go back to it by using the back arrow of the navigator.

7.2.3.3 The use of bibliographic artifacts

Another interesting function the researcher could use while working on a document is the "Link document to project" option. It allows establishing a link between the document and one or more of the projects where the researcher participates, thus indicating the use he intends to do of it. In order to do so, the researcher only has to select the project(s) with which he wants the document to be linked. In this way, once he or one of his team members opens the project space of the specified project(s), a link to the document will be displayed. This facilitates sharing information among the team members and helps build the memory of the project, at the same time the project is developed.

In addition, if he finds the document interesting, he may use the "Add document to my favourites" function, which will create a link to the document from his personal list of favourite documents. This can help him create his personal library of selected documents and facilitates the access to these documents because the list of selected documents is inserted into his personal space. Moreover, he can access this list by selecting the "Explore my documents" function in the Documents module.

In addition, reaggregating pieces of information is easily done through several ways. Thus, the researcher can search all the annotations containing a specific word, look at a concept in order to obtain all the information that has been identified in relation to it, or go to a projects' space in order to see all the information used and created through the development of the project. This may be highly useful for preparing new documents, which usually involves mobilising information from several sources at the same time, and not working on individual documents as in the processing stage.

7.2.3.4 The capitalization of bibliographic artifacts

Once having worked with the document, the researcher can access the information related to it, complement it by looking at the information of the researchers who use the document, the available information on the identified concepts, or the projects using it. This allows him to continue his bibliographic research by capitalizing on the artifacts identified or created by his fellows. In addition, his own work is registered on the prototype, thus allowing others to profit from it. Additionally, the approach should facilitate the identification of knowledgeable people thanks to the traces it makes of the author of each artifact. The principle we have used is that a researcher can acknowledge the areas of interest of one of his fellows by looking at information such as the preferred documents and concepts, the projects in which he participates and the annotations he makes. This information can constitute a kind of profile of each researcher of the organization. Moreover, neither creating nor updating this profile represents additional work because Basic Lab takes in charge the maintenance of the trace, as each researcher chooses and creates artifacts. Similarly, the information of each project is gathered as the work is done, which facilitates its updating, sharing and identification by fellows.

In the previous paragraphs we have explained the use a researcher could do of the prototype while developing his bibliographic research. The explained functions are operational in the actual version of the prototype. Thus, it is necessary to observe the researchers' reactions towards the approach in order to verify its potential for supporting their activities. This is the subject of the next section.

7.3 The Researchers' Reactions towards Basic Lab

In order to verify the potential benefits an approach such as the one we propose could bring to research organizations, we proceeded to try it out. The first stage of these trials consisted on the introduction of some documents, already annotated and indexed to the database. The documents are a sample of the ones used for the development of our project. Most of them treat KM issues. Afterwards, we installed the prototype on a server, which allows us to try it in order to analyze the possibilities it offers to a group of researchers for performing their activities.

A first group of researchers participated in the trials. One PhD student and three Masters' students formed the group. They where all working on subjects related to KM, which we thought could motivate them to explore the contents already registered in the prototype. One first session was held in order to present Basic Lab and its main functionalities. After that, they could access the prototype anytime they wanted as a support to the projects in which they where working. As the prototype traces the actions done by each person by adding the author and the date of each action, we leaned on this functionality to follow the utilisation they did. After a four-week period, we observed a weak utilization of the prototype. Therefore, we proceeded to interview the members of the group to know the reasons why they did not use the prototype as frequently as we had expected.

The interviews revealed that we seem to suffer from what is called the "capture bottleneck" (Motta, E., et al., 2000). In fact, according to (Motta, E., et al., 2000), "many schemes for registering shared resources and providing structured descriptions founder on the crucial "capture bottleneck" – the envisaged beneficiaries of the system simply do not have the motivation or time to invest in sharing". Consequently, users limit their use of the prototype to some consultation of the contents already registered in it, but prefer not to invest the time required for registering new information.

Given this observation, we proceeded to make individual sessions with a second group of researchers (one engineering student, three masters' students, four PhD students, one temporary professor, one assistant professor and one professor)[144]. In these sessions, we

[144] Annex 14 presents a brief report about the results of these sessions. They correspond to a series of interviews to 10 members of the GILCO Laboratory: one engineering student, three masters' students, four PhD students, one temporary professor and one assistant professor. These interviews treated two subjects: Researchers' practices regarding bibliographic research and BASIC Lab. In addition, another interview was done to a visiting

showed Basic Lab in order to gather their feedback about the prototype. The result was a very positive feedback from all the researchers to whom we have presented the prototype. In effect, the researchers agree on the appropriateness of the functionalities present in the prototype and in their potential for supporting the bibliographic research. Regarding this activity, they also agree on the difficulties for managing it and in the lack of well-adapted computing tools.

However, they also agree on not wanting to key in information in order to register it on the prototype, particularly regarding the indexing information, which could be automatically inserted. Nevertheless, we note that, as we knew this functionality existed on some of the commercial tools available, we did not try to re-develop it. In fact, in Basic Lab we try to show the functions illustrating our approach and therefore, we only implemented the functions involving a certain degree of novelty. The researchers, who have tried the prototype, have remarked the lack of some of the functionalities available in existing tools, perceiving it as a weakness of the prototype. This has put a constraint to the analysis of the possibilities it offers. However, what is perceived as a weakness was in fact partly done in order to concentrate on the innovative aspects of the prototype and as a way of "forcing" the exploration of the approach used. In fact, we tried to avoid the problems other researchers have reported regarding the usability tests, where the new features proposed are hardly used. The explanation given is that users do not notice them or are not able to figure out how to use them (Peterson Bishop, A, 1999). In our case, despite the remarks regarding the absence of functionalities such as the search on the full text of the documents, the researchers explored the prototype and confirmed the suitability of the implemented functionalities for supporting the bibliographic work. Thus, using the prototype was highly intuitive. Moreover, the researchers could easily understand the principle of navigating through the artifacts for finding additional research paths to explore or colleagues to contact. This was greatly appreciated. Additionally, they remarked the possibilities the approach offer for exploring artifacts from different points of view. They also welcomed the benefits of being able to examine the artifacts used in projects working on related subjects.

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professor to know his opinion of BASIC Lab. The results of this interview are presented through this section and not in the annex.

Regarding the ergonomics of the prototype, we implemented some details for facilitating its use. Thus, each of the five elements in the prototype has a corresponding colour. The colour of the screen changes according to the type of element being visualized. For example, the colour related to documents is grey. Whenever a document is visualized, the screen turns grey. Conversely, the colour related to concepts is pink. Thus, if, while visualizing the information on a document, a researcher clicks on the link to a related concept, the screen will turn pink, showing the researcher, he has changed from one space into another. The researchers who tried out the prototype perceived this and appreciated it. Moreover, one of them suggested using this principle for differentiating between public and private spaces. In addition, the buttons allowing accessing the functionalities regarding the five basic modules are always available to the leftmost side of the screen, which facilitate accessing them. Additionally, the functions for annotating documents or parts of them are accessible at the right side of the Acrobat® window (where the document appears), thus facilitating adding annotations through a pop-up window.

One aspect we think seems to require further analysis is the definition of the use a researcher wants to give to certain documents. In Basic Lab, projects can be declined into sub-projects unlimitedly. Thus, an activity in a project can be represented as a sub-project where some artifacts will be used and created. In this way, a PhD student can, for example, create a project called "PhD_Project" where his documents, concepts and annotations will be stocked. He can also create sub-projects according to particular aspects of his project. Thus, he could for example, create a sub-project called "Dissertation", and create several sub-projects for each one of the chapters of his dissertation. However, the researchers did not intuitively understand this. Nevertheless, once we explained the principle we have used, they agreed on the possibility of structuring projects in this way.

Another aspect that seems to be somewhat confusing is the distinction between domain and concept. In Basic Lab, documents can be indexed according to their domain. However, these domains are neither pre-defined nor hierarchically organized. Their purpose is just allowing rapidly positioning a document into one or more domains. In addition, Basic Lab gives the possibility of searching documents by domain, which we thought could be useful for rapidly acknowledging the scope of the available documents in a specific domain. On the contrary, concepts correspond to hierarchical structures, where scientific concepts can be organized in different levels of granularity. At the higher level of the hierarchy, one would find concepts corresponding to the domain. For that reason, concepts can also be searched by domain. Thus, for example, in Basic Lab, one finds the domain of "Knowledge Management", and the concepts of knowledge, information, competences and many others used in the domain. This differentiation seems to be somewhat confusing. However, once we explained the principle used, researchers rapidly understood how to work with it. Nevertheless, this aspect needs to be further studied in order to define how to cope at the same time with the required flexibility in the structuring and creation of concepts and the coherence of the structure.

Summarizing, the feedback we have obtained from the researchers to whom we have shown Basic Lab has been highly positive. They all agree in the need for better support to the bibliographic work and on the suitability of the functionalities proposed in Basic Lab. For that reason, we think that the results obtained are mostly encouraging for continuing working towards the improvement of the support to researchers for performing their activities. Therefore, in the next section, we present some of the improvements we think would be necessary in order to successfully implement the proposed approach.

7.4 The Possible Improvements of Basic Lab

Given the results of the trials we have done with the prototype, we think that the improvement of some aspects could enhance the benefits obtained from it. Apart from the use of advanced computing techniques for developing the real tool, the trials we have done have learned us some facts we think could be highly valuable.

First, it is necessary to implement the features usually found in the search tools, as users expect to find them. Among these features, we can find the possibility of multi-criteria searches, the re-organization of the found results according to the criteria chosen by the user and the searches in full text. In addition, a functionality to collect references from online and Web databases, avoiding the need to re-tape them, seems to be key for effectively deploying the approach at a research organization. Additionally, given that some editors' sites allow exporting references directly into the databases of tools such as Reference Manager, ProCite and EndNote[145], it would be necessary to make sure the tool can import references from such sites. Complementarily, one researcher has suggested inserting links between Basic Lab and the external information sources. This would facilitate the search of information, as the researcher could use only one tool in order to find all the information he may require.

In addition, features such as the organization of the personal library and of the project library according to certain criteria would be appreciated. Another important aspect could be to extend the information provided to users for assessing the relevance of papers by enriching the information provided about particular aspects of it, such as details about the author and cited references (Peterson Bishop, A., 1999). In the current version of the prototype, we took into account the use of a given document as an indicator of its pertinence, revealed through the researchers and the projects using or having used it. However, it seems to be desirable to enrich this information in order to facilitate the selection of documents. This aspect can be particularly important for graduate students, who, because of their insufficient knowledge of the scientific network of their field, do not recognize famous authors, in the way more experienced researchers usually do. In addition, this feature could provide bases for extracting important information about a field, such as the main universities or research centres working in it, which could prove its utility in more strategic aspects related to the management of the research laboratory (e.g. cooperation agreements, students exchange, and so on).

Additionally, as following citations is a common information-seeking strategy used by researchers, it would be interesting to include links to the documents cited by a document that can also be found in the system. Thus, a document would include links to the cited references as well as to the materials using the document, creating a reference chain of documents present in the system.

Another aspect that we think would be useful is the incorporation of visualization support. This could provide a graphical representation of the structure of the information in the system, which could facilitate the comprehension of the approach implemented and of the information contained in the system.

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[145] See, for example, http://www.sciencedirect.com.

Other possible improvements deal with practical aspects aimed at reducing the practical tasks involved in the manipulation of bibliographical artifacts. For example, it would be desirable being able to differentiate between identified documents potentially useful for treating a question and already read ones, as a usual practice is to acquire more documents than one actually can read.

Regarding annotations, it would be good to implement the functionality of control of sharing level. This would allow researchers to define the people or groups with whom they want to share their annotations. This is because researchers seem to be reluctant to write all the thoughts a text may generate when knowing all their colleagues can see them. Complementarily, it would also be good to be able to select which annotations one wants to be displayed regarding a document, or if ones wants to visualize the original document (without any annotation).

Regarding the structuring of the concepts, it would be necessary to incorporate an application to control the dynamic creation of domain ontologies. This, by itself, is an important project that needs to be addressed for keeping the coherence of the artifacts registered in the tool.

7.5 Conclusions

As we have shown in the previous chapters, the design of the approach, which we have called BASIC Lab for Bibliographical Artifacts for ScIentific Knowledge Creation in Research Laboratories, took as start point the actual scientists' practices related to the bibliographic artifacts. The analysis of these practices led us to identify five basic elements: Documents, annotations, concepts, projects and researchers. These elements interact during the development of a research project in order to create new knowledge. For that reason, BASIC Lab contains these five modules.

For developing the prototype of the approach, we have used the specifications defined in the previous chapter. For this purpose, we have used a PHP – MYSQL combination, by using EasyPHP, together with Macromedia Dreamweaver MX for the development of the portal. We remark that the focus of this prototype is not on the information technology. Its objective is to verify the benefit our approach can bring to a research organization.

Thus far, we have developed a first version of the prototype. In the actual stage, it is possible to add documents and annotations, to create projects and concepts and to access the researchers' information. These elements can be linked together in order to use them for a particular interest. For example, a researcher can add a document he finds interesting. Then, he may define the zones of the documents he considers to be the most interesting ones, establish where in the document are the explanations of the scientific concepts used by the author(s) and add his comments to the document or to zones of it. He could also select the elements he wants to keep in his personal list of favourites and choose the elements he thinks could be used in a particular project. Similarly, other team members of a project could also include other artifacts thought to be useful for studying a phenomenon, sharing in this way a part of their knowledge. Additionally, the elements in the prototype are hyperlinked, to facilitate the navigation among them and the access to the different artifacts.

Thus, the next step has been trying it out in order to see the possibilities it offers to researchers for the capitalization of the bibliographical work done in the framework of a research project. After introducing a sample of the documents we use in our own project, we presented present Basic Lab to a first group of researchers. Afterwards, the researchers could use it anytime they wanted as a support to the projects in which they where working. We could follow the utilization of the prototype trough the traces of the actions done by each person. After a four-week period, we observed a weak utilization of the prototype. Therefore, we proceeded to interview the members of the group to obtain feedback about the prototype and know the reasons why they did not use it as frequently as we had expected. According to their answers, most of them have chosen not to continue using the prototype mainly because of the "capture bottleneck" (Motta, E., et al., 2000). This, in spite of the recognized possibilities of the prototype and the current inconveniences faced. Thus, one very important improvement would be to facilitate the capture of the references in order to diminish the time spent in this task and motivate researchers to exploit its full functionalities.

Given the results obtained from the first group of researchers, we did a series of individual sessions with a second group of researchers. In these sessions, we showed Basic Lab to each researcher, allowing him to try it out. We then discussed with him his impressions regarding the prototype. This discussion was also held with the first group of researchers. The comments of all the researchers to whom we have shown the prototype, express a positive impression of the approach and the functionalities available in the prototype. Its functioning is easily grasped and learning the bases for using it is done in only a few minutes because it is mostly intuitively understood. This encourages us to continue working towards to improvement of the support offered to researchers for the realization of their activities.

Conclusions and Perspectives

> "Presumably man's spirit should be elevated if he can better review his shady past and analyze more completely and objectively his present problems. He has built a civilization so complex that he needs to mechanize his record more fully if he is to push his experiment to its logical conclusion and not merely become bogged down part way there by overtaxing his limited memory. His excursion may be more enjoyable if he can reacquire the privilege of forgetting the manifold things he does not need to have immediately at hand, with some assurance that he can find them again if they prove important." (Bush, V., 1945)

Conclusions

We are interested in research organizations, as institutions committed to the creation of new knowledge. Then, knowledge management practices result of great interest. In order to study this aspect, we performed several activities, which we will briefly summarize hereafter.

• Summary of the work done

Given our interest in the knowledge creation process at research organizations, we wanted to study the possibilities of introducing knowledge management practices within the framework of the quality management implementations actually being done at several research organizations. To this end, we made a fieldwork in order to know the reality of these organizations and collect information on the impact the implementation of quality management has on knowledge management practices in research activities.

The fieldwork allowed us to note that even if the main activity of the analyzed organizations is the production of knowledge, the systems are centred on the formalization of certain activities. These activities are mainly the ones that support the research activity. The implementation involves the setting up of information systems that manage the quality documents and a part of the documents of the organization, primarily the final documents (and not the intermediate results or the artifacts). In addition, we have shown that the quality management systems observed do not really address the knowledge management aspect in research, and that the document management practices implemented do not fully address the artifacts of research. The cause seems to be the lack of methodologies and of real experiences that would formulate a way to set up a quality management system for the research activities. This, we think, would need to lean on knowledge management methods for improving these activities.

Then, in order to look for ways of introducing formal knowledge management practices in the research activities, we carried out an analysis of the activities realized during the research process and of the information used and generated by these activities. This analysis enabled us to define that a very important aspect is the capitalization of the knowledge produced and acquired during the realization of a project. For this purpose we propose to lean on the capitalization of the artifacts produced during this stage of a project in order to facilitate its re-utilization.

Our next step was to analyze the way in which these artifacts are indeed produced. For this purpose, we schematized the way in which research projects are realized by inspiring in the SADT modelling technique. This work allowed us to identify more than a hundred artifacts produced during the realization of research projects. We then classified them in three categories: Artifacts related to the bibliography, artifacts related to the management of the project and artifacts related to the intermediate results. The problem was now to find ways to allow the capitalization of these three kinds of artifacts. For this reason, we studied two main ways: methodological tools and software tools.

Regarding the methodological tools, we did not find any tool we considered adapted to the research activity. This leaded us to the study of the software tools. We studied the existing knowledge management tools offered in the market, the tools focused on the support to research activities and the tools developed by researchers for managing scientific knowledge. Though we assessed the current richness of the offer, we concluded that it still lacks a tool that facilitates the capitalization of the bibliographical artifacts. These are the ones identified and created by researchers when doing a bibliographical research in the framework of research projects. Therefore, we decided to define the specifications of an approach for capitalizing these artifacts, as a way to capitalize at least part of the knowledge acquired and developed in a research organization.

In order to set the bases for the definition of the specifications, we studied the current researchers' practices for dealing with their bibliographical work. We relied on three aspects: scientific literature on the subject, direct observation of our colleagues and our own experience. This allows us to know from the inside the situation and to grasp observations done externally. Together, these aspects helped us elucidate some aspects we should take into account for the development of the approach. Among them we find: the importance of journal articles, the increasing importance of electronic sources, the value of personal contacts for identifying important documents, the maintenance of personal collections of preferred documents, the generalized use of annotations and the participation of several researchers in the writing of new documents, among others. In addition, these practices are studied in three times: The identification, the processing and the use of bibliographic artifacts. Given the similarity between these stages and the activities included in the KM Cycles proposed in the literature, we propose to use, as our KM Cycle, these three stages along with a capitalization stage, given the need for preservation and sharing mechanisms allowing capitalize knowledge.

The analysis of the researchers' practices regarding bibliographic work allowed us to define a series of requirements regarding the management of the bibliographic artifacts. The defined requirements deal with the management of different artifacts (e.g., documents, annotations) and to the identification of knowledgeable people, whose work should be contextualized (mainly through the definition of the project and the subjects of interest). Furthermore, the study of these requirements gives as a result the identification of five basic elements interacting during the realization of bibliographic researches. These elements are: Researchers, Projects, Documents, Annotations and Concepts. Thus, researchers and artifacts interact during the realization of the bibliographic research, which serves as a support to the whole research activity. In this sense, this kind of research complies with the differentiation we have made between knowledge and artifacts[146]. Therefore, we can define two ways for capitalizing knowledge in order to facilitate the scientists' activities. That is: through the people who held the knowledge we want to capitalize, or through the artifacts representing the knowledge. However, the approach we intend to design can only deal with artifacts. For that

[146] See Chapter 3 Knowledge Management in Research Organizations.

reason, the identification of knowledgeable people should rely on artifacts as an indication of the areas in which each individual is knowledgeable or at least interested.

Thus, although managing artifacts is an important aspect, it is also desirable to find ways to access the knowledge held by people. The way for doing it is to exchange knowledge with fellows. Accordingly, the elements we have identified are artifacts representing a part of the scientists' work. Their management intends to facilitate the interaction between researchers and bibliographical artifacts. In order to do this, we lean on the concepts of "expert finders" and of artifact. The former should foster the direct exchanges of knowledge among researchers, while the latter should keep an explicit support helping to convey knowledge. In addition, as we acknowledge the importance of organization by projects in research, we use the concept of project memory as the bases for the construction of the organizational memory. In order to formalize our conception of it, we defined the general structure we have conceived. In it, scientific concepts act as a support to access the artifacts. However, we do not aim the definition of a domain ontology, as we pretend to present researchers the different existing positions regarding a same concept. This could provide the "redundancy" condition claimed by (Nonaka, I., et al., 2000) in order to foster knowledge creation.

These theoretical bases served us for the definition of the specifications of the approach. In order to do so, we made a functional analysis, a scenario-based analysis and we modelled the system with UML. Then, these analyses where used for defining the specific functionalities of the approach. This allowed us to develop a prototype of the approach that partially implements them. The prototype is based on the five elements identified (Researchers, Projects, Documents, Annotations and Concepts). Links among these elements allow navigating through them in order to identify artifacts and people to capitalize knowledge. In the prototype, a researcher may access documents to a database, enrich them with annotations, index them according to the scientific concepts found in them and link them to the on-going projects. It is also possible, to choose his favourite documents and concepts in order to keep a personal digital library and to easily access new materials identified by fellow researchers in relation to the chosen concepts. Additionally, researchers may add concepts to a hierarchical structure collectively created at the laboratory level. This feature accounts for the dynamic character of the scientific knowledge, to which a fixed domain ontology could not respond.

In order to verify the potential benefits an approach such as the one we propose could bring to research organizations, we proceeded to try the prototype out. The first stage of these trials consisted on the introduction of some documents, already annotated and indexed, to the database. The documents are a sample of the ones used for the development of our project. Most of them treat KM issues. A group of graduate students participated in the trials. One PhD student and three Masters' students formed the group. They where all working on subjects related to KM, which we thought could motivate them to explore the contents already registered in the prototype. One first session was held in order to present the prototype and the main functionalities. After that, they could access the prototype anytime they wanted as a support to their projects. As the prototype traces the actions done by each person by adding the author and the date of each action, we leaned on this functionality to follow the utilisation they did. After a four-week period, we observed a weak utilization of the prototype. Therefore, we proceed to interview the members of the group to know the reasons. Their answers show that although they find the prototype interesting and the functionalities useful, they do not want to spend the time necessary to entry new information in it. This is what is known as the "capture bottleneck".

Given the results of this first stage, we proceeded to a second stage where we did individual presentations of Basic Lab to some researchers. We then interviewed them regarding the implemented functionalities. Their insights verify the necessity for better support to the bibliographic work and the suitability of the implemented functionalities and in general of the approach proposed in the prototype. Nevertheless, we recognize the limitations of the work we have done. Therefore, in the next section we will discuss some aspects we think could be interesting to take into account for future initiatives.

• Discussion of the work done

The work done has resulted in the definition of the specifications of an approach to support the bibliographic work done in the framework of research projects. The work involved several aspects, some of which, we recognize, could have been done more comprehensively. Thus, for example, the realisation of a fieldwork could have been done in further detail in order to better analyse the activity and take into account a richer sample of experiences, points of view and of concrete practices. Also, the sample of research organizations we worked with presented some common characteristics that could be perceived as a bias. Notably, the participation of a same consultant in all the processes of implementation of quality management systems could involve a bias in the observed experiences. Thus, observing a greater number of research organizations, involving different approaches in the implementation of the quality management system, could help improving the understanding of the implementations of quality management systems.

Similarly, the study of the impact of these systems into the knowledge management practices could be deepened through a richer fieldwork allowing the realization of analyses such as the specificities related to scientific domains. In this sense, an important aspect of our work has been the reflexivity it has involved. This means that, while observing research activities, we have also advanced in our own research. This has two main implications: On one hand, we experience the activity by ourselves, which can lead to a better understanding of the research activity. On the other hand, this experience is done in the framework of an engineering research laboratory, which can induce a bias in the vision we have of research activities. Thus, a deeper analysis in other fields could be of great value.

Conversely, an aspect that was difficult to do was the trial of the prototype of our approach. Apparently, we did not sufficiently envision the impact that the limitations of the prototype (precisely because it is a prototype and does not involve a robust development) would have on these trials. In addition, other aspects also seem to play a role. For example, remembering people about the possibility of using a new tool seems to be important for its introduction. Also, explaining in detail the scenarios of utilization foreseen and the ways of taking full advantage of the functionalities proposed seems to be important in order to successfully introduce a new tool.

Thus, the learning we have made through the realization of this project goes beyond the specific theories of the scientific domains supporting this work. Conducting trials of the prototype, preparing interviews, undertaking a fieldwork, among others, are all important competences that will surely be very useful in future research enterprises.

In addition, the work has allowed us to uncover many aspects, notable regarding the research activity, which could be of great interest to study. For that reason, we are encouraged to continue working towards the improvement of the support to the research activity. Hence, we envision several research perspectives it would be possible to pursue. We will briefly present them hereafter.

Perspectives

The main motivation of our project has been finding ways to support the research activities. We have explored one specific aspect we think may contribute to this purpose. However, certain aspects could be further studied and others could complement the work done. In this section, we present some of them.

• Related to the prototype

This project has resulted in the development of a prototype of an approach for managing bibliographic knowledge. As its purpose is to show the possibilities of our approach for research organizations, its development did not use the latest advancements in information technologies. In addition, the trials we have done suggest possible improvements regarding the functionalities offered to the users. Thus, there are certain aspects whose study could be deepened. We will briefly explain them hereafter.

o The use of advancements in information technologies

In the information technology field there have been interesting technologies that could be very useful in a system such as the one we propose. Thus, the use of techniques for the analysis of texts, for example, could be incorporated. In addition, the existing developments include several interesting features we have not intended to reproduce, but whose utility we recognize. Regarding the commercial tools, important features to include would be the ones offered by EndNotes to capture and manage references, the visualization of references offered by RefViz and Omniviz or the annotation support offered by IMarkup. The tools issued from research activities offer other interesting features. Examples are: the support to the construction of an ontology offered by ScholOnto and the indexing capabilities of Beluga. Additional examples are the retrieval of document components and the linking of articles citing a document offered by DeLIver and the automatic extraction of attributions regarding the concepts contained in scholarly documents as the work of (Pham, S. B. and Hoffmann, A., 2004) does, to name just a few. Additionally, aspects such as the implementation of features allowing the information push could be useful.

In addition, as there have been differences in the sharing of annotations, a desirable feature would be being able to choose which annotations will be shared and which ones will not. Furthermore, as annotations are made not only to the document in general, but to specific parts of it, it should be possible to provide a functionality allowing specifying types of annotations to visualize. In addition, it would be possible to imagine managing not only texts but multimedia documents and annotations, in order to allow further flexibility and to facilitate the sharing and analysis of multimedia records.

In summary, the development of the actual tool could take advantage of the features already offered by the existing tools, and incorporate the new technologies being developed. This should not replace the central aspect of the approach, which is the capitalization of the insights researchers may add to the bibliographical artifacts contained in the system, together with the capitalization of the ways of mobilizing scientific concepts in the framework of a research project.

- Knowledge Extraction issues

The utilization of tools implementing approaches such as the one we propose allows the maintenance of data bases where different artifacts are kept. In the actual stage, the prototype allows inferring important information such as which are the well-regarded works, which could be done by looking into the documents mostly used in a given domain. Nevertheless, as the time passes and an approach such as Basic Lab is used, it would be probably possible to extract this kind of information in order to allow researchers to concentrate on other aspects of the activity (such as the analysis of information).

- The users' practices

Apart from the technological possibilities we could possibly incorporate in the tool, another important source of improvement is the insights of the users that have tried it and the observations regarding the use of bibliographical documents done in different frameworks. Thus, it is necessary to continue observing in detail the practices of researchers in order to identify possible evolutions due to aspects such as the technological changes or the specificities in particular scientific domains. This observation could result in the definition of additional functionalities, the improvement of the actual ones and the specification of additional ways of structuring the information, in order to better support researchers.

In addition, aspects such as the will to share information, or the importance granted to the maintenance of the privacy should be studied in detail, as it seems to be an important issue when wanting to implement a system like the one we propose.

Additionally, the observation of the utilization made by the users of the tool could support the definition of criteria to maintain the information contained in it, by defining aspects such as the removal of artifacts in order to keep only the necessary information and avoid the information overload.

- The management of paper

An aspect in which we have not deepened into is the management of paper. Although there have been claims regarding the growing importance of electronic documents, it is also true that paper documents are still very present in the research activity, and, in general, in many diverse activities. It would be then interesting to search for ways of better supporting its management. Some efforts are focused to the digitalization of documents. However, it is possible to expect that it will be still necessary to continue to manage paper. Therefore, it could be interesting to offer a good support for this.

- The analysis of legal issues

In addition to the improvement of the functionalities of the prototype, it would be desirable to study aspects such as the implications that the existing regulations (e.g. copyright legislation) may have on the definition of methods and tools for supporting the activity. In the specific case of Basic Lab, where we propose to keep an electronic copy of the documents, it would be necessary to study what the actual legislation allows to do. Additionaly, the trends in the legislation could also be an important subject to study.

Another aspect it would be important to analyse would be the legislation regarding the mobility of researchers in order to define aspects such as the artifacts a researcher could take with him if he ever leaves a research laboratory. In this case, it would be important to take into account the respect to the intellectual property regulation. A related aspect to explore would be the management of confidential information, where special practices should be implemented.

- Regarding other application fields

In this work, we have concentrated on the bibliographical research done in research laboratories, particularly in academic research laboratories. The objective is to arrive to manage scientific contents with the support of information technologies. Therefore, a possible extension of our work would be the utilization of the approach proposed in industrial research centres, analyzing the differences that may exist in the scientists' practices and the adaptations that could be needed. Furthermore, it would also be interesting to analyse if the approach proposed could be used as a basis for managing knowledge in other activities, such as the design activity, with which certain similarities are perceived (e.g. the dynamic character of the activity, the collaborative dimension, the importance of inscriptions, etc.). For this purpose, it would be necessary to analyse the practices used and define what modifications should be done. These observations would mean implementing customization features allowing accounting for particular practices or defining special applications according to specific domains.

- ## Related to the research activities

In this work, we have focused on one particular aspect of the research activity, which is the bibliographical research. What's more, even in this case, we have only analysed a part of this activity (leaving aspects such as the identification of important journals, conferences, Web sites, etc. out of the scope of analysis). However, there are many more aspects to analyse and different ways of analysing them. Consequently, deepening into the study of research activities would imply looking into aspects such as the ones we mention hereafter.

- The management of knowledge in research

An important aspect that would be interesting to explore is the analysis of further opportunities for capitalizing knowledge. A first aspect could be the definition of methods for extracting knowledge out of the already available resources. Thus, some aspects such as the capitalization of strategies used in bibliographic research, the capitalization of information important for bibliographic research (e.g. important conferences) and the extraction of important information of the artifacts contained in the tool (e.g. external knowledge maps) should also be explored.

It would also be possible to focus on complementary aspects to the bibliographical research. Thus, in our model of research projects, we explored one aspect, the definition of the state of the art based on the bibliographical research. However, the possibilities of capitalization of knowledge could be found at all the stages of the development of a project (management of data, dissemination practices, etc.). Consequently, further research would be necessary in order to define methods to profit from this knowledge by capitalizing it while a project is being developed and by facilitating its re-utilization once it has finished. In addition, the detection of best practices used in the organization could be an important aspect to take into account in order to better support the activity. Another issue that could be interesting would be the possibility of using creativity techniques in order to favour the creation of knowledge in scientific environments.

Another aspect that would be interesting to study would be the evaluation of the knowledge produced. The objective would be to find ways of measure the results obtained from the activity, not only through the publications made but through the results of the activity. A possibility to explore would be the creation of new concepts or the re-interpretation of existing concepts. This would mean trying to measure the result of the research activity and not only the containers (e.g. publications).

- The study of aspects related to the management of research

Apart from the aspects related to the management of knowledge in research, there are other important aspects that could be studied related to the management of the activity. Among these we find: the management of research projects, the strategic aspects such as the distribution of funds among concurrent projects, the technological watch, the establishment of means to measure of the advancement of on-going projects, the management of the intellectual property, the analysis of popularization and dissemination practices, the improvement of means to transfer research results to the industry, the study of the time invested by researchers in the different activities done in order to find the barriers and inconveniences they face (language barriers, formatting of documents, etc.), the importance of the collocation of research teams (vs. the possibility of working from different locations), and the management of competences of researchers.

- The analysis of the problematic through different fields of knowledge

In this work, we have mostly used literature coming from the field of knowledge management. However, fields such as epistemology, cognitive science and sociology of knowledge (particularly, Sociology of scientific knowledge), among others may provide very important insights for analysing the knowledge production process in scientific environments. Doing this would probably imply using a different methology aimed at deepening into aspects such as the effects that the social networks may have on the management of knowledge. In this way, we could expect to deep into the understanding of the scientific dynamics.

Also, aspects such as the economic flows around the scientific activity could help better understanding it. In this sense, the study of the flow of capitals and the return over investment (ROI) for the government, as well as for the innovative enterprises, could be of great interest. In the same line of thought, one could try to analyse the ROI of activities such as the bibliographic research activity have for a research organization.

- The enlargement of the scope of analysis

In this work, we have looked into the knowledge production process as it occurs inside a research organization. However, it is known that several research initiatives are carried out in cooperation with other organizations. Thus, the knowledge production process involves a network that goes beyond the limits of a single research institution. Hence, it would be desirable to analyze the functioning of these networks in order to define if the approach proposed could support this kind of research initiatives and what would be the necessary adjustments, or define ways in which this support could be attained.

A further enlargement of the analysis could also involve the study of the initiatives proposed in order to support research activities at a macro level (e.g. national and international). Also, the study of the functioning of the institutions that are involved in the research activities, but that do not carry them out could help deepening into the understanding of the dynamics of research activities. Among these institutions one finds the financing organizations, research observatories, research ministries and so on, whose functioning, as well as the regulations some of them impose, can have an important impact the activity of research organizations.

In addition, the analysis of the impacts of some socio-political and economic facts may have on the research organizations could be interesting. Aspects such as the mobility of researchers and the establishment of cooperation agreements could be affected by these facts, which would impact the research activity.

- The comparison of the research activity developed in different contexts

As a support to the development of the present work we have observed some research organizations located in Grenoble (France). These organizations are public laboratories attached to academic institutions. Thus, the organizations we have observed are a particular kind of research organization located in a specific geographic location. For that reason, it would be interesting to compare the possible differences and similarities in the practices used in different contexts. Potential parallels could be done between public and private laboratories, French laboratories and those located in other countries, research-only laboratories vs. research and academy laboratories, and so on. These comparisons could have important implications in aspects such as the implementation of quality management systems, the implementation of knowledge management practices, the regulations to take into account and in the concrete practices done by their researchers.

Conversely, it would also be interesting to look at the research developed by the industry and particularly by SME's (Small and medium enterprises) whose activity is based on the research capabilities. The analysis of specific cases of technology-intensive enterprises, recognized as successful, could lead to the identification of best practices and specific conditions allowing them to be successful. Here, aspects such as university-industry relations, management of intellectual property and marketing of technology could be especially important.

- Related to quality management in research

When we started our project, we were interested in quality management as a way of improving the research activities. The fieldwork we undertook did not show an important use of quality management for the basic research activities. However, some laboratories have started to think about the introduction of quality management in the PhD projects. This, we think, is an indication of the potential use of quality management in the basic research activities. Thus, an interesting perspective is the follow up of these experiences. We think that this stage in the introduction of quality management can lead to the verification of our initial hypothesis regarding the use of KM in order to introduce quality management in the research activities. For the moment, one of the laboratories whose work on quality management we have followed has started working on the improvement of the support of the bibliographic work done in the framework of PhD projects. This, from our point of view, verifies the importance of this activity, and, at the same time, the need for better support to it.

Complementarily, it would be interesting to analyse the subject of the quality of research. The objective here would be to see if the actual mechanisms to evaluate the quality of research results (e.g. evaluation by peers) do effectively accomplish their role and analyse the other mechanisms that lead to the validation of scientific claims.

- The measurement of the possible benefits obtained from management initiatives

An important question, for which we still do not have an answer, is the actual benefits that initiatives such as quality management and knowledge management can indeed be obtained by the organizations enterprising such endeavours. In the case of research organizations, the definition of indicators becomes especially cumbersome, as the sole bibliometric indicators do not seem to be enough to measure the impact obtained. Thus, though we are convinced that approaches such as the one we propose in this work could be beneficial for the research activity, we still do not count with the necessary tools for clearly demonstrating it.

- Related to managerial initiatives

Through the realization of this project, we have taken into account two approaches: quality management and knowledge management. Both of them could be seen as managerial initiatives aimed at improving the way organizations function. Consequently, several issues of interest could be studied. Among them we find:

  - The comparison of different managerial initiatives

Through this work we have dealt with issues belonging to quality management and knowledge management, trying to see if, in the framework of the research organizations, the implementation of the former could involve aspects of the latter. We have seen that there are several works analysing different aspects in which these two approaches could be related. In our particular case, we have perceived some similarities such as the analysis of the way activities are done. This same kind of analysis has been observed in other works such as the implementation of ERP's (Enterprise Resource Planning systems). Thus, it would be interesting to analyse the relations existing among different managerial initiatives. In what are they similar and where are the important differences? Is it possible to define potential complementarities? This could help clear up the panorama of managerial initiatives and serve as a tool for organizations wanting to undertake some of them.

  - The definition of comprehensive approaches for supporting organizations

Through this work we have aimed at defining aspects complementing the actual aspects taken into account in the implementation of quality management systems in the research organizations we have observed. Further analysis would surely uncover several aspects that could complement the quality management system by observing the activities done in research organizations. The result could be a comprehensive approach aimed at supporting the activities done in research organizations. However, research organizations are just a particular kind of organization among the several that exist. Thus, one could study other organizations in order to analyze their specificities and try to define how to support their activities.

Final Remarks

With the presentation of the possible perspectives this work generates, we finish the report about the activities we have performed in the framework of this dissertation. In it, we started by observing reality in order to propose an approach aimed at supporting researchers in the performance of their activities. For this reason, the work has implied trying to lean onto methods and theories from different disciplines, notably sociology (for the field work) and industrial engineering (for the definition of the proposed approach). This exercise has been both challenging and enriching, at the same time that incites us to envision future endeavours where this approach could probably also prove its utility.

“A single conversation across the table with a wise man is worth a month’s study of books.” Chinese Proverb

Annexes

Annex 1. Definitions of the notion of Knowledge

We have seen mainly four types of definitions:

1. Those that present knowledge as a collection of information
2. Those that present knowledge as linked to action
3. Those that present knowledge as beliefs
4. Those that present knowledge as meaning
5. Those that present knowledge as restrictions, heuristics and inference procedures

In the group of definitions presenting knowledge as a collection of information we find examples such as the definitions proposed by Becker and by Sena and Shani:

- Knowledge can be defined as the right collection of information at the right time. (Becker, G., 1999)
- Knowledge refers to an activity of treatment of information, activity in which interpretative filters take part... each individual interprets the information he receives through a "vision of the world" that is particular for him (Bandler and Grinder 1970) (Sena, J. A., Shani, A.B., 1999)

Regarding the definitions presenting knowledge as the use of information for action, we find definitions such as the ones proposed by Woolf, Turban and Beckman that specify problem solving together with others that link this concept to action in general:

- Knowledge is organized information applicable to problem solving. – Woolf (Beckman, T.J., 1999)
- Knowledge is information that has been organized and analyzed to make it understandable and applicable to problem solving or decision making. – Turban (Beckman, T.J., 1999)
- Knowledge is reasoning about information and data to actively enable performance, problem-solving, decision-making, learning, and teaching. – Beckman (Beckman, T.J., 1999)
- Knowledge can be seen as the entirety of cognitions and abilities which are used by individuals to solve problems. This comprises theoretical perceptions as well as pragmatic

day-to-day rules and guidelines and is an organised set of statements of facts or ideas, presenting a reasoned judgement or an experimental result. (Weber, F. et al., 2002)

- Knowledge can be defined as stabilized structures in long-term memory, structures that constitute the basic knowledge for action and comprehension of messages and situations (Cordier et al. cited by Crépault and Nguyen, 1990, in Simoni, 2001).
- Knowledge is an awareness of the efficiency and effectiveness of different courses of action in producing particular outcomes based on experience. (Sonnenwald, D. H. et al., 2004)

In the group presenting knowledge as beliefs, we find, among others, the definitions provided by some of the most renowned authors in the field:

- Knowledge is a justified true belief. (Nonaka, I. et al., 2000)
- Knowledge consists of truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how and is possessed by humans, agents, or other active entities and is used to receive information and to recognize and identify; analyze, interpret, and evaluate; synthesize and decide; plan, implement, monitor, and adapt – i.e., to act more or less intelligently. In other words, knowledge is used to determine what a specific situation means and how to handle it. (Wiig, K. M., 1999)
- Knowledge is seen as a justified personal belief that increases an individual's capacity to take effective action. (Benbya, H. et al., 2004)
- Knowledge is the whole set of insights, experiences, and procedures that are considered correct and true and that therefore guide the thoughts, behaviours, and communications of people. – van der Spek and Spijkervet (Beckman, T.J., 1999)
- Knowledge is the result of human experience and reflection based on a set of beliefs and residing as fictive objects in people's mind. (Frank, C., 2003)

In the group of definitions presenting knowledge as meaning, we find definitions such as the one proposed by (Croasdell, D.T. et al., 2003). He presents a different point of view regarding what knowledge is, and defines it as "meaning based on personal interpretation of inputs."

Finally, we find a conception of knowledge as restrictions, heuristics and inference procedures. This is the case of the definition provided by Sowa:

- Knowledge encompasses the implicit and explicit restrictions placed upon objects (entities), operations, and relationships along with general and specific heuristics and inference procedures involved in the situation being modelled. – Sowa (Beckman, T.J., 1999)

Annex 2. Definitions of the notion of Knowledge Management

We have identified mainly four visions regarding KM:

1. Those that see KM as a matter of information technology
2. Those that see KM as a strategic matter
3. Those that see KM as a process that facilitates knowledge sharing
4. Those that see KM as a process to create and increase the use of knowledge

In the first group, that sees KM as a matter of information technology we find definitions such as:

- KM is suggested as a methodology for creating, maintaining, and exploiting a well-structured knowledge repository (Stewart, 1991, 1995; Wiig, 1993). (In Baek, S. et al., 1999)
- KM involves collecting and storing knowledge expressed in various forms to facilitate its conservation, access, sharing and reuse. (Falquet, G., Mottaz-Jiang, C.-L., 2003)
- KM is a process of explicitation, modelling, sharing and appropriation of knowledge [Dieng and al., 1998]. (In Bekhti, S., Matta, N., 2003)

In the second group, that sees KM as a strategic matter, we find definitions that concentrate on the result to attain from KM:

- KM is getting the right knowledge to the right people at the right time so they can make the best decision. – Petrash (In Beckman, T.J., 1999)
- KM is the process of capturing a company's collective expertise wherever it can help produce the biggest payoff. – Hibbard (In Beckman, T.J., 1999)
- KM is the formalization of and access to experience, knowledge, and expertise that create new capabilities, enable superior performance, encourage innovation, and enhance customer value. – Beckman. (In Beckman, T.J., 1999)

- KM is the systematic, explicit, and deliberate building, renewal, and application of knowledge to maximize an enterprise's knowledge-related effectiveness and returns from its knowledge assets. – Wiig (In Beckman, T.J., 1999)
- KM involves the identification and analysis of available and required knowledge, and the subsequent planning and control of actions to develop knowledge assets so as to fulfil organization objectives. (In Beckman, T.J., 1999)
- KM is the explicit control and management of knowledge within an organization aimed at achieving the company's objectives. – van der Spek (In Beckman, T.J., 1999)
- KM applies systematic approaches to find, understand, and use knowledge to create value. – O'Dell (In Beckman, T.J., 1999)
- KM is a sequential set of activities related to observation, instrumentation, and optimization of the firm's knowledge economies. It is an officially sanctioned and formally valued set of activities within the firm that involve the construction or making of knowledge; the transformation of tacit knowledge into processes, practices, materials, and cultures; the distribution of knowledge throughout the firm's value chain and, the application and dissemination of knowledge to problems and opportunities – making knowledge work. Knowledge management also monitors, measures, and facilitates these activities. (Sena, J. A., Shani, A.B., 1999)

The third group concentrates on the sharing dimension. Some examples are:

- KM is perceived here as comprising organizational practices that facilitate and structure knowledge sharing among knowledge workers. With successful knowledge management we refer to practices of knowledge sharing that have become embedded in the ongoing work processes of an organization. In other words, we perceive the success of knowledge management as related to the degree in which sharing knowledge has become a taken-for-granted part of the routine practices within the organization. (Huysman, M., Wit, D. de, 2003)
- KM is the systemic and organizationally specified process of acquiring, organizing and communicating knowledge of employees so that other employees may make use of it to be more effective and productive in their work (Alavi & Leidner, 1999). (In Benbya, H. et al., 2004)

- Using the term agent as it is used in economics, knowledge management is the intentional influence of an agent or group of agents on an organizational environment in which knowledge is produced, refined, and used by other agents. (Swanstrom, E., 1999)
- To manage knowledge means to know what is known, who knows it, how it has been applied, and how it can be further leveraged and shared (Wilma D. Abney, DaimlerChrysler Corporate University). (Haas, R., et al., 2003)
- KM is a set of managerial activities related to the generation, codification and sharing of knowledge. - Davenport and Prusak, 1998 (In Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001)

In the fourth group, that sees KM as a process to create and increase the use of knowledge, we find definitions such as:

- KM is a managerial function that consists in directing, organizing, coordinating and controlling the activities and the processes intended to amplify the utilisation and the creation of knowledge within an organization according to two strongly intricate complementary purposes: a patrimonial purpose and a durable innovation purpose; purposes based on their economic, human, social and cultural dimensions. (Grundstein. M., 2002)
- KM is the collection of processes that support the creation, dissemination, and utilization of knowledge between appropriate individuals, groups within an organization, or independent organizations (Spek & Spijkervet, 1996; Wiig, 1993) (In Baek, S. et al., 1999).
- KM means all activities to understand, focus on, and manage systematic, explicit, and deliberate knowledge building, renewal, and application (Wiig, 1997). (In Disterer, G., 2002)
- KM comprises any process or practice of creating, acquiring, capturing, sharing and using this knowledge, wherever it resides, to enhance the learning and performing in organisations. (Weber, F. et al., 2002)
- KM is the systematic, goal oriented application of measures to steer and control the tangible and intangible knowledge assets of organizations, with the aim of using existing

knowledge inside and outside of these organizations to enable the creation of new knowledge, and generate value, innovation and improvement out of it (Wunram et al., 2002).

Annex 3. The Knowledge Management Models

Author	Knowledge manipulation activities								
	1	2	3	4	5	6	7	8	9
Frank, C., 2003	Identify	Acquire	Structure	Combine	Share	Distribute	Use	Preserve	Evaluate
O'Dell , 1996 *	Identify	Collect	Adapt	Organize	Apply	Share	Create		
Holsapple and Joshi, 1997 *	Acquire	Select	Internalize	Use	Generate	Externalize			
Wiig, K. M., 1999	Creation and sourcing	Compilation - transformation	Dissemina-tion	Application and value realization					
Coleman, D., 1999	Creation	Valuation and metrics	Mapping and indexing	Transport, storing, and distribution	Sharing				
Probst, 1998	Knowledge Goals	Identification	Acquisition	Development	Distribu-tion	Preservation	Use	Measure-ment	
Van der Speck and Spijkervet, 1997 *	Develop	Secure	Distribute	Combine					
Ruggles, 1997 *	Generation: Creation, Acquisition, Synthesis, Fusion	Codification: Capture, Representation	Transfer						
Beckman, 1997 *	Identify	Capture	Select	Store	Share	Apply	Create	Sell	
Grundstein, M., 2002	Location,	Preservation,	Sharing,	Actualization					
Huysman, M., Wit, D. de, 2003	Retrieval	Exchange	Creation						
DeBella and Nevis, 1998 *	Acquire	Disseminate	Utilize						
Hoog, R. de, 1999	Review,	Conceptualize,	Reflect	Act					
Gartner Group, 1998 **	Create	Organize	Capture	Access	Use				
Davenport and Prusak, 1998 **	Generate	Codify	Transfer						
Arthur Anderson and APQC, 1996 **	Share-create	Identify	Collect	Adapt-organize	Apply				
Mertins, Heisig and Vorbeck, 2001 **	Create	Store	Distribute	Apply					
Benbya, H., et al., 2004	Generation	Storage	Distribution	Application					

Source: The models marked with the asterisk (*) where cited by (Beckman, T.J., 1999). The ones marked with double asterisk (**) where cited by (Benbya, H., et al., 2004). The ones without any one of these marks where taken directly from the cited documents.

Annex 4. The Knowledge Capitalization Methods

Method	Type of knowledge capitalized	Elements for the analysis of Knowledge	Method Used for gathering information	Models built	Phases	Results	Software
MSKM	Domain Knowledge	Information, Meaning, Context, Structure, Function, Evolution	Interviews to experts and documents	Context: - Domain model - Activity model Meaning: - Concept model - Task model	- Framing phase: Definition of models to built - Modelling phase - Knowledge book: Gathering of models and other information of a knowledge domain.	- Knowledge book - KM operating system	MKSM, to represent the diagram and to search knowledge.
MEREX	Product and process solutions or design rules	Technical memory and project memory	Experience reviews	-	- Creation of cards - Sharing of cards - Exploitation of cards	- Cards containing innovations and problems found (history of decisions) - Checklists containing the cards titles allowing the analysis of the problem before taking a decision	- Lotus notes for the sharing phase - Browser for the exploitation stage
Workshop FX	Knowledge regarding an activity	- Terms, data	"Observer-apprentice" technique	-	- Choosing observer-apprentice - Observation of practitioner - Writing of instruction notice (IN) - Validation of IN - Incorporation of IN in the technological base	- "Reasoned catalogue" (Including inventory of documents, data used and lexicon)	NOMINO: Helps indexing documents through a morpho-syntactic analysis of the text (in French)
Componential Frame-work	Domain Knowledge	Activity defined according to: task, information and method. Information: Information and knowledge consulted and built through the tasks Method: How the information is used	Modelling	- Domain model: information and knowledge emanating from the application domain - Case model: information used in a specific case	-	- Knowledge-based system - Ontology describing the vocabulary of the domain	KREST: Allows the representation of the different perspectives and the relations among them. Allows the navigation through the graphical and textual descriptions.

Method	Type of knowledge capitalized	Elements for the analysis of Knowledge	Method Used for gathering information	Models built	Phases	Results	Software
Common-KADS	Domain / Occupation Knowledge	3 paradigms: Description, Action and Declaration Decomposition of the world in objects, actions and reasoning	Interviews, Observations and study of documents	- Practical model: identification of expertise elements - Cognitive model: Structuring of knowledge - Informatics model: Transfer to software programme	- Practical Modelling: Interviews, modelling and validation - Cognitive Modelling: Interviews, modelling and validation - Assessment: Assessment and definition of orientations	- Knowledge-based systems (Additionally, Domain ontology, occupational reference frames)	K-Station
CYGMA	Design knowledge	Six categories of knowledge: Singular, terminological, structural, compartmental, strategic, operational	Interviews to experts and study of documentation	-	-	- Occupational reference frames (includes: Occupational glossary, semantic booklet, rules notebook, operational handbook) - Knowledge bases	- Not
Rex	Activity memory (R&D and design)	Knowledge elements	Interviews to experts and study of documentation	- Experience sheets - Domain model	- Choosing the person whose activities will be modelled - Modelling of activities - Interviews (Includes 20 – 30 interviews for the construction of experience sheets, followed by additional interviews for their completion and their validation) - Consolidation meeting: Verification of comprehension of experience sheets	- Experience sheets: Includes: Lexicon, descriptive model, knowledge sheets, documents - Domain model: Includes a descriptive model (objects network showing the different points of view) and a terminological network (lexicon)	REX: For retrieving the knowledge elements and navigating through the elements

Method	**Type of knowledge capitalized**	**Elements for the analysis of Knowledge**	**Method Used for gathering information**	**Models built**	**Phases**	**Results**	**Software**
Gameth	Crucial Knowledge	Tangible and intangible knowledge	Modelling	- Modelling of significant processes	- Determination of "significant processes" - Distinguishing "determining problems" - Determining crucial knowledge	- Repertory of crucial explicit knowledge - Repertory of the agents carrying tacit knowledge - Index of the agents in the possession of knowledge - Document defining tacit knowledge whose elucidation is possible - Recommendations regarding tacit knowledge whose elucidation is possible	-

Source: The source of the information contained in this table is (Dieng, R., et al., 2000), with the exception of the information regarding the Gameth method, which was extracted from (Grundstein M., 2002).

Annex 5. The Direct Extraction Methods

Method	Elements structuring the design rationale	Knowledge Capitalized	Result	Software Tool
IBIS (Dieng, R., et al., 2000)	- Issues: Articulated as questions - Positions, which can potentially resolve the issue - Arguments, which can support or object to a position (9 types of links)	- Design Problems	- Tree structure representing the dialog and decisions taken through complex design problems	gIBIS
PHI (Regli, W. C., et al., 2000)	- Issues - Answers - Arguments (only 1 type of relationship)	- Design issues: Two methods used: Deliberation and decomposition	- Outlines representing design issues	Not
QOC (Dieng, R., et al., 2000)	- Questions: Identifying key design issues - Options: Providing possible answers to the Questions - Criteria: For assessing and comparing the Options	- Design problems	- Structuring of the design space (decisions made in the design process) as a web of alternative Options for solving the Questions.	Not
DRL or Function Representation (Regli, W. C., et al., 2000)	- Functions	- Description of the functioning of a device	- Top-down approach to represent a device: Overall function and behaviour of each component	Not
DRCS System (Dieng, R., et al., 2000)	- Entities : allowing the representation of objects and assertions - Relations: allowing the definition of relations between the entities	- Design rationale in concurrent engineering process	- Synthesis model: Decomposition of the artifact in modules and sub-modules - Evaluation model: Achievement of the specifications of the artifact - Intent model: Showing the decisions taken for solving problems - Versions model: Showing the design alternatives - Argumentation model: Showing the argumentation for an alternative	Not

Method	Elements structuring the design rationale	Knowledge Capitalized	Result	Software Tool
DRAMA (Dieng, R., et al., 2000)	- Goals - Solution options - Options Chosen	- Design rationale of a design project	- Solution tree	DRAMA : It offers hyperlinks to documents and allows the generation of HTML reports
EMMA (Dieng, R., et al., 2000)	- Goals - Plans to achieve goals - Context of the defined plans - Changes - Evolution process	- Design and maintenance of complex, evolvable systems	- Representation of the design process as a solution structure showing the relationships among goals and plans	EMMA: Based on hypertext links
DIPA (Dieng, R., et al., 2000)	- Two problem-solving types are distinguished : Synthesis and analysis	- Design rationale	- Representation of the decision-making	MEMO-net : It allows structuring exchanges
KBDS-IBIS (Regli, W. C., et al., 2000)	- Uses an IBIS structure and introduces three classes of objects : Artifacts, steps and tests	- Design rationale	- Representation of the design-rationale	KBDS
Method of Bekhti and Matta (Bekhti, S., Matta, N., 2002)	- Problems Objects - Arguments - Suggestions - Participants	- Design rationale	- Representation of the project memory as well as the context and decision-making (keeps track of meetings) from four points of view: Problem solving, Argumentation criteria, Evolution of the Problem Solving and Chronological view.	Not

Source: The main sources of the information contained in this table are indicated next to the name of the methods shown.

Annex 6. The Knowledge Management Systems

(Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001) propose a typology of KM categories consisting of:

- Intranet-based systems: They are private networks. They provide a hypertext structure that eases the navigation between information chunks and may facilitate the sharing of dynamical and linked information (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002).
- Electronic document management (EDM): These are also called Content Management tools. They are repositories of important corporate documents and provide features such as cataloguing and indexing (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). According to (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001) documents are "an efficient way to exchange explicit knowledge that, organized and combined, can lead to new knowledge."
- Groupware: (Coleman, D., 1999) defines Groupware as the "software that supports the ability for two or more people to communicate and collaborate". They aim at overcoming barriers resulting from distances in time or in space (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). (Coleman, D., 1999) proposes a Groupware taxonomy composed of: Electronic mail and messaging, Group calendaring and scheduling, Electronic meeting systems, Desktop video and real-time data conferencing (synchronous), Non-real-time data conferencing (asynchronous), Group document handling (Group editing, shared editing work, group document/image management and document databases), Workflow, Workgroup utilities and development tools, Groupware services, Groupware and KM frameworks, Groupware applications and Collaborative-Internet-based applications and products. He also remarks the importance of Web-based KM tools for the transportation, creation, distribution and sharing of knowledge.
- Workflow: These systems "support standardized business processes" (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). They aim at establishing and accelerating the process flow, following its steps and tracking each activity that composes the process. Thus, they "make explicit the knowledge that is embedded in standard processes, mainly

supporting the formal codification of existing knowledge." (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002)

- Artificial intelligence-based systems: (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002) distinguish mainly three types of Artificial intelligence-based systems: Expert systems, CBR (Case Based Reasoning) systems and neural networks. The expert system "contains a limited domain knowledge base, an inference mechanism to manipulate this base and an interface to permit the input of new data and user dialog. An expert system is built on the observation of a specialist at work and on the mapping of part of his knowledge into derivation rules" (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). CBR systems support users trying to solve problems, by allowing them to verify if a similar problem (stocked as cases) has already been solved (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). Finally, Neural networks "use statistical instruments to process cause-effect examples and learn the relationships involved in the solution of problems." (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002)
- Business intelligence (BI): Business Intelligence (BI) is a "set of tools used to manipulate a mass of operational data and to extract essential business information from them" (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). According to (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002), BI systems comprehend: Front-end systems (DSS-Decision Support Systems, EIS-Executive Information Systems and OLAP-On-Line Analytical Processing tools; Back-end systems (data warehouse, data mart and data mining) and Data Base Management Systems -DBMS. These tools help reveal trends and patterns in data. Some of them focus on information related to clients, making an interface with CRM (Customer Relationship Management) systems and enhancing database-marketing policies (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002).
- Knowledge map systems: They work like yellow-pages that contain a "who knows what" list. A knowledge map does not store knowledge (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001), but allow accessing knowledge held by people, facilitating "the development of interpersonal connections around topics of interest" (Hertzum and Pejtersen, 2000). It provides an expert locator feature that helps users find the best-suited experts to work on a specific problem or project. These systems are also known as expert finders or expert/expertise recommenders (Yiman Seid, D., Kobsa, A., 2003). (Hertzum

and Pejtersen, 2000) propose two approaches for supporting searches for people: "to extend document retrieval systems by explicitly exploiting the fact that documents tell a lot about the work activities of their authors and thereby provide a rich description of the authors' experiences and competencies"; and "to develop models for classifying people's expertise" (without eliciting people's expertise). These approaches are presented as "the "ask a program/document" and "ask a person" paradigms into information seeking" (Yiman Seid, D., Kobsa, A., 2003). (Yiman Seid, D., Kobsa, A., 2003) present some examples of expert finders. The approaches used by these tools go from Asking people to indicate their expertise by selecting from a list (HelpNet[147]) to more sophisticated ones that use Semantic Indexing (LSI) for analyzing technical documents (Expert/Expert-Locator-EEL, also called "Bellcore Advisor" or "Who Knows")[148] or using binary term-weight matrix-based procedures (DCB algorithms) to analyze documents (The Associative retrieval method[149]). Other follow the URLs people visited (The MEMOIR system[150]) or browse paths of experts to find relevant documents (The Expert Browser[151]).

- Innovation support tools: They "are software that contribute to knowledge generation along the product design process" (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002). Therefore, they are mostly used in industrial R&D. Among the features they present we find (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002): technical database where patents, articles and research projects are recorded, graphic simulation features and combinatory tools, which help to consider unusual possibilities in the design of innovations.
- Competitive intelligence tools: These tools support the collection and analysis of qualitative information about the environment evolution (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002).

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[147] (Maron, M. E., et al., 1986).

[148] (Lochbaum, K. E. and Streeter, L. A., 1989).

[149] (Kimbrough, S. O., and Oliver, J. R., 1994).

[150] (Pikrakis, A., et al., 1998)

[151] (Cohen, A. L., et al., 1998)

- Knowledge portals: (Benbya, H., et al., 2004) defines knowledge portals[152] as "the category of portals, which aim at providing employees with in-time relevant information they need to perform their duties and make efficient business decisions." According to (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2001) portals "integrate heterogeneous information sources, providing a standard interface to the users." Some interesting characteristics of knowledge portals are: they provide a single point of access to information (Benbya, H., et al., 2004); they go beyond organizational boundaries (Baroni de Carvalho, R., Araújo Tavares Ferreira, M., 2002); they provide a shared information workspace for the creation, exchange, retention and reuse of knowledge. (Benbya, H., et al., 2004); they can be customized according to the preferences of each knowledge worker (Benbya, H., et al., 2004); and they are focused on the business processes of the company (Benbya, H., et al., 2004).

[152] According to (Benbya, H., et al., 2004) knowledge portals are also called Employees Portals, Enterprise Intranet Portals, Corporate Portals, Business-to-Employees Portals and Business-to-Employees Systems.

Annex 7. Definitions of the notion of Ontology in the KM literature

We have found the following definitions of the term "Ontology":

- (Bekhti, S., Matta, N., 2003): "A document or file that formally defines the relations among terms."
- The Standard Upper Ontology Working Group: "A set of concepts, axioms, and relationships that describe a domain of interest."
- (Becker, G., 1999): "A set of objects, definitions of the properties of each object, and the relationships among those objects.
- (Buckingham Shum, S., et al., 1999): "The construction of knowledge models which specify concepts of objects, their attributes, and interrelationships." [153]
- (Falquet, G., et al., 2003): "A set of interrelated concepts together with their definition expressed in a formal language (having a formal syntax and a formal interpretation)."
- (Mizoguchi, R., and Kitamura, Y., 2000): "An explicit specification of objects and relations in the target world intended to share in a community and to use for building a model of the target world."
- (Liao, S-H., 2003): "The knowledge integration of different representations of the same piece of knowledge at different levels of formalization."
- (Van Heijst, G., et al. 1997a): "An explicit, knowledge level specification of a conceptualization"
- Guarino and Giaretta, 1995 (Dieng, R., et al, 2000): "A logical theory that partially but explicitly accounts for a conceptualization" [154]

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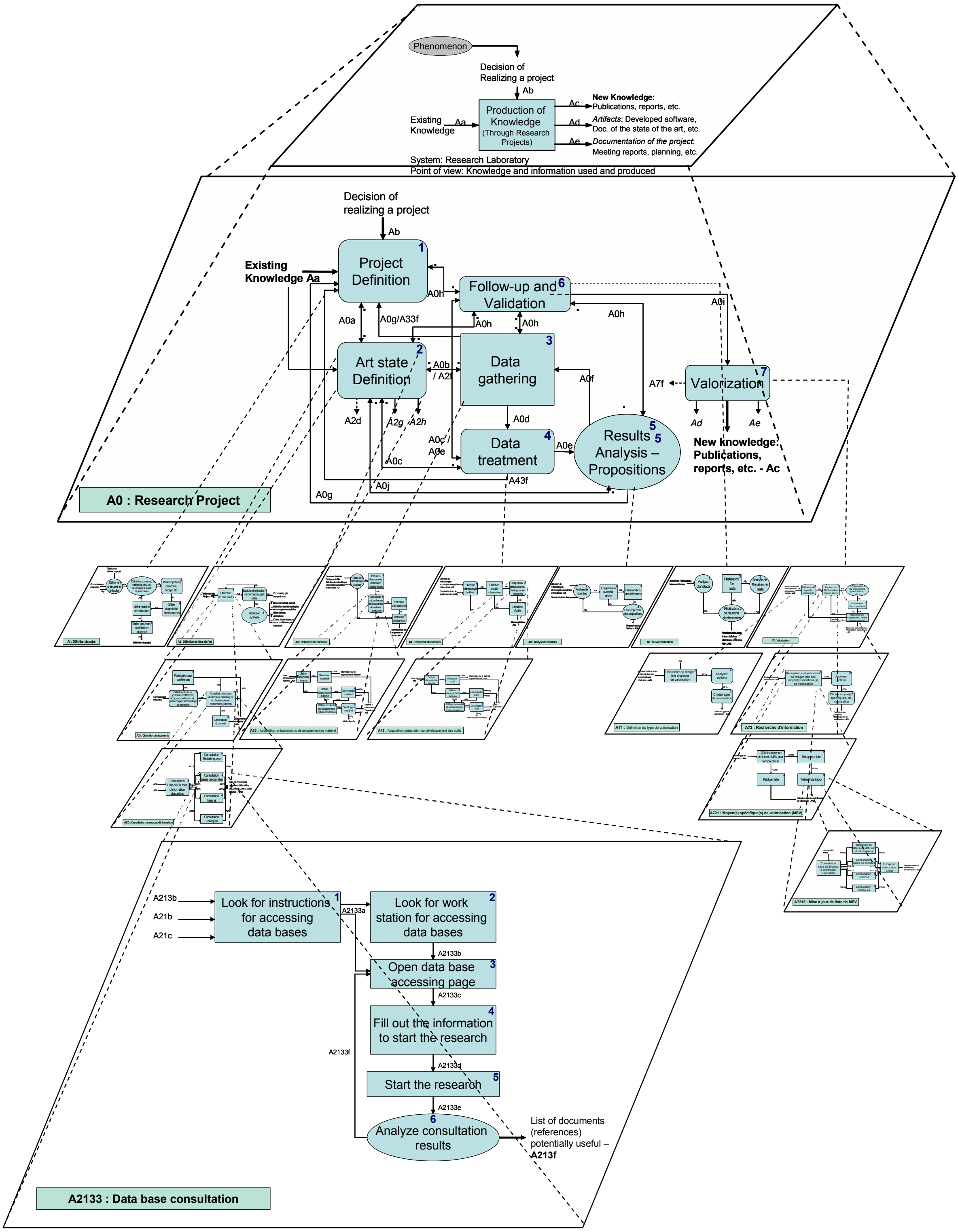
[153] In this perspective, "a knowledge model is a specification of a domain, or problem solving behaviour, which abstracts from implementation-centered considerations and focuses instead on the concepts, relations and reasoning steps characterizing the phenomenon under investigation." (Buckingham Shum, S., et al., 1999)

[154] Conceptualization is defined as "an intentional semantic structure which captures the implicit rules forcing the structure of a piece of reality" (Dieng, R., et al, 2000).

Annex 8. Representation of Research projects



Annex 9. List of artifacts identified through the modelling of research projects

Conventions	Abbreviation	Meaning
	B	Bibliography
	PM	Project Management
	IR	Intermediate Results

Process	Link	Artifact	B	PM	IR
A : Research Process	Aa	Publications, reports, books, etc.	X		
	Ab	Meeting reports		X	
	Ac	New publications, reports, etc.	X		
	Ad	Artefacts : software, doc. of the state of the art, etc.			X
	Ae	Documentation of the project : meeting reports, planning, etc.		X	
A0 : Research Project	A0a	Document defining the project - Meeting report		X	
	A0b	Document of the state of the art	X		
	A0c	Instructions for the treatment of data, manuals for using software			X
		Description of a new methodology used for the treatment of data			X
	A0d	Raw data on the system in study - Report			X
	A0e	Treated data			X
	A0f	Results of the data analysis, proposals			X
	A0g	Definition of additional fields, theories and methodologies to study			X
	A0h	Intermediate results resulting from the other activities			X
	A0i	Validated results			X
A1 : Project definition	A1a	Problematic, minutes of meetings		X	
	A1b	Fields, methods, etc that can be considered to analyze the phenomenon	X		
	A1c	Definition of objectives, personnel, budget, etc. - minutes of meeting		X	
	A1d	Analyze of available resources		X	
	A1e	Minutes of meeting (decision of non-viability -- need for redefining the characteristics of the project)		X	
	A1f	Minutes of meeting (decision of viability)		X	
A2 : Definition of the state of the art	A2a	Documents of the field of study (Contains A21d).	X		
	A2b	List unknown fields, methods, etc and that could help to analyze the phenomenon	X		
	A2c	Documents, judged as relevant, underlined and annotated	X		
	A2d	Documents considered to be irrelevant	X		
	A2f	List of methodologies and concepts likely to be used	X		
	A2g	Annotations	X		
	A2h	Lists of important authors, journals, conferences, research teams, etc	X		
A21 : Gathering of Documents	A21a	Lists of authors, journals, conferences, research teams and key words relevant for the problem	X		
	A21b	List conferences where it is possible to participate	X		
	A21c	Report of participation in conference		X	

Process	Link	Artifact	B	PM	IR
	A21d	Proceedings of the conferences	X		
	A21e	List of potentially useful references (Contains A213e - A213f - A213g - A213h)	X		
A213 : Consultation of information sources	A213a	List of accessible libraries	X		
	A213b	List of accessible Data bases	X		
	A213c	List of sites on Internet	X		
	A213d	Agenda - colleagues' contact information		X	
	A213e	List of documents found in the library	X		
	A213f	List of documents found in the data bases	X		
	A213g	List of documents found on Internet	X		
	A213h	List documents recommended by colleagues	X		
A2133 : Consultation of data bases	A2133a	Instructions to access the data bases		X	
	A2133b	Available Station			
	A2133c	Database ready for consultation			
	A2133d	Form of consultation of database filled out (usually "on-line")		X	
	A2133e	List of found references	X		
	A2133f	Insufficient results => Necessity of carrying out additional consultations - Annotations	X		
A3 : Data Gathering	A3a	Decision on the methodology to be used for obtaining data - Minutes of meeting		X	
	A3b	List of instruments required for obtaining data		X	
	A3c	Instruments ready to use			X
		Handbooks about the use of instruments (technical Documentation)			X
	A3d	Description of the methodology used for obtaining samples - Updated laboratory notebook			X
	A3e	Non-suitable methodology - Minutes of meeting		X	
	A3f	Decision on the need of additional instruments - Minutes of meeting		X	
A33 : Acquisition, preparation or development of material	A33a	Confirmation of availability of material		X	
	A33b	Confirmation of unavailability		X	
	A33c	Confirmation of availability		X	
	A33d	Confirmation of unavailability		X	
	A33e	Definition of specifications		X	
	A33f	Information on the availability of material (date)		X	
	A33g	Instructions			X
A4 : Data treatment	A4a	Decision on the methodology of data processing to be used - Minutes of meeting		X	
	A4b	List of necessary tools		X	
	A4c	Tools			X
		Instructions of use			X
	A4d	Definition of new tools - Report, documentation for obtaining the tools		X	
	A4e	Definition of new methodology - Report		X	
A43 : Acquisition, preparation	A43a	Confirmation of availability of tools		X	
	A43b	Confirmation of unavailability		X	
	A43c	Confirmation of availability		X	

Process	Link	Artifact	B	PM	IR
or development of instruments	A43d	Confirmation of unavailability		X	
	A43e	Definition of specifications		X	
	A43f	Information on the date of availability of the tools		X	
	A43g	Instructions of use			X
A5 : Analysis of results	A5a	Analyzed data - Report - Laboratory notebook updated		x	X
	A5b	Annotations on the comparison with the state of the art	X		
	A5c	Report of differences with the state of the art	X		
	A5d	Drafts of proposals			X
	A5e	Drafts of proposals to be compared with the state of the art (to check the novelty)			X
A6 : Validation	A6a	Intermediate result analyzed considered ready for validation			X
	A6b	Decision on the tests of validation to be realized - Minutes of meeting		X	
	A6c	Results of tests - report		X	
	A6d	Report with the analysis of the results of tests - Laboratory notebook updated		X	
A7 : Valorisation	A7a	Choice of the type of valorisation		X	
	A7b	Definition of the specific means of valorisation		X	
	A7c	Proposal(s)			X
	A7d	Proposal(s) submitted			X
	A7e	Communication of refusal of proposal to selected type of valorisation or specific means of valorisation		X	
	A7f	Refused proposals			X
A71 : Definition of the type of valorisation	A71a	List of valorisation options			
	A71b	Analyzed options (probably there will be no document)		X	
A72 : Information search	A72a	List of specific means of valorisation			X
	A71b	Analyzed options (probably there will be no document)		X	
A721 : Specific Valorisation Means (SVM)	A721a	Definition of the existence of the list of SVM		X	
	A721b	List of SVM			X
	A721c	Definition of the inexistence of the list of SVM		X	
A7213 : Actualisation of the list of SVM	A7213a	List existing mailing lists		X	
	A7213b	List of accessible Data bases		X	
	A7213c	List of sites on Internet		X	
	A7213d	Colleagues' contact information		X	
	A7213e	Malls with information on SVM			X
	A2113f	Information on SVM found in data bases			X
	A2113g	Information on SVM found on Internet sites			X
	A2113h	Information on SVM given by Colleagues			X

Annex 10. The identified commercial knowledge management tools

Conventions	
Abbreviation	**Meaning**
DM	Document Management
Col	Collaboration Among People
Pro	Project Management
CM	Content Management
CA	Content Aggregator
DR	Document Routing (through a process)
KA	Knowledge Agent
DIT	Data Integration tools
LI	Linkage of documents by hypertext
EL	E-Learning
BPM	Business Process Management
SE	Search Engine
GV	Graphical Visualization
AU	Autres
TB	Text Base
ODBC	Open Database Connectivity

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Entreprise		**Open Text Corporation**															
Livelink	Livelink Enterprise Suite																Dynamic collaboration and knowledge sharing between individuals, teams, and organizations. Enables to conduct virtual meetings (including sharing desktops), leverage advanced calendaring and scheduling functionality, and create project workspace and discussions. Manages all aspects of Web content creation, automate all of your key business processes, search engine, Web-based course management, records management, persistent access to organized and secure workspaces based on job roles and predefined Views, secure wireless access.
	Livelink for Knowledge Management																Enables to capture, organize, classify, and share all of its explicit and tacit knowledge in a single, secure Web-based repository. you can unite silos of information, automatically capture knowledge from key e-mail discussions, discover knowledge in internal and external knowledge sources, identify subject matter experts, and quickly find knowledge using sophisticated search and retrieval capabilities. Three types of workspaces that reflect the different ways in which people work: the Enterprise Workspace; Project Workspaces; and Personal Workspaces. Allows you to associate metadata with documents. You can assign a unique e-mail address to folders in the Livelink for Knowledge Management repository, thereby allowing users to e-mail document attachments directly into a particular folder. **Multiple taxonomic classifications** can be associated with documents in their original locations. extends search functionality to Web-based content sources outside of the Livelink repository. users can create special queries to monitor various data sources, including the Livelink repository, shared network drives, external Web sites, and any integrated databases

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	Livelink for Collaboration																Provides a Web-based environment for project teams to work together. It includes online meeting and calendaring capabilities. provides the ability to set up threaded discussions to enable teams to brainstorm and debate issues. **Each project workspace has a project overview page** that allows team members to view the project status and activity within the project. provides integrations with Microsoft Windows desktop applications. In a typical project workspace you'll find: • Threaded Discussions • Task Lists • Meeting Rooms • A Project Calendar • and • Documents & Folders. Users can setup the notification agent to alert them by e-mail whenever a new task is created or a task is overdue. **users can drag and drop multiple files and folders between their desktop and the Livelink for Collaboration repository**. MeetingZone provides:When the meeting is over a summary document is sent automatically to the attendees.
	Livelink for Business Process Management																Designed to ease the creation, deployment, modification, and management of business processes
	Livelink for Content Management																Web content management application for authoring, managing, dynamically assembling, and delivering content to the Web.
	Livelink Review Manager for Acrobat																Provides a flexible process for managing multiple, parallel reviews of documents in Adobe PDF. This allows users to securely and concurrently review and add comments to un-modifiable PDF versions, and record their comments and changes in Livelink. Authors or editors can then consolidate comments from reviewers and create a new version of an original document in Livelink.
	Livelink for Document Management																lifecycle management for any type of electronic document, access control, version control, compound documents, audit trails, workflows for automating document change request, review, and approval processes, extensive indexing and search capabilities. Multiple taxonomic classifications can be associated with documents in their original locations. **Rate the value of a document and write a critique that is saved with the document and viewed by other users, lists of the most recent and frequently accessed documents.**
Other products	BASIS																search and retrieval solution. excels at managing hybrid document collections consisting of both documents and their associated metadata. blend of unstructured and structured content, where a subject specialized caretaker often adds metadata and detailed topical analysis.
	BRS/Search™																Search engine for publishing large quantities of dynamic, customized information in all Web-based applications requiring sophisticated functionality and appearance.
	Query Server™																meta search tool that broadcasts a single query across a set of Web-enabled search engines, unifying access to multiple information sources
	BRS Spider™																Enables the crawling and indexing of any number of Web-based knowledge sources, and provides a unified set of detailed results within BRS/Search.™
	Coreport																enables you to rapidly deploy a single enterprise integration portal
	FirstClass																converges powerful features such as, e-mail, voice messaging, fax, shared online work- spaces and instant messaging, enables users to securely access and share information
	iRIMS																Provides comprehensive, full lifecycle management of all your corporate records and information holdings in paper or electronic format.
	LaunchForce																uses rich media and rich tracking to quickly deploy mission-critical information to corporate audiences
	ODOC																Suite of object and workflow imaging solutions used to control the information that is critical to your day-to-day operations.
	Open Image																Automated workflow, imaging and document management provides you with the power to capture, store and distribute your information workflow. **Concurrent access to documents.**
	Techlib																Library management solution for automating cataloging, searching, circulation, serials control and acquisitions functions for books and other library materials.
Entreprise		**Accelrys**															
Discovery	DS ProjectKM																Software for pharmaceutical, chemical, and materials research. It is an Oracle®-based groupware system that integrates applications and enriches

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Studio																	collaboration between research team members from Biology through to late stage lead optimization. DS ProjectKM enables you to create and manage experiments, folders, queries, job runs, and associated data.
Other Products	Link to list and details																
Entreprise		**iManage**															
iManage WorkSite	iManage WorkDocs™ Overview																iManage WorkSite is a comprehensive out-of-the-box document management, collaboration, knowledge management, portal, workflow and business process automation solution—all seamlessly integrated on a highly scalable and secure Internet platform.
	iManage WorkTeam																
	iManage WorkKnowledge																
	iManage WorkPortal																
	iManage WorkRoute																
Entreprise		**Inmagic**															
Inmagic's Knowledge Management Solutions	BiblioTech PRO																Inmagic Inc. is a global provider of content and information management software and services. Our products and services organize and deliver enterprise content, seamlessly integrate internal and external content sources and deploy business-critical information to corporate portals, intranets, extranets and the Web.
	DB/TextWorks																
	DB/Text® WebPublisher																
	DB/Text PowerPack																
	DB/Text ODBC Driver																Posibilité de combiner plusieurs bases de données.
Entreprise		**Tikit**															
Tikit Solutions	Knowledge Portal																For lawfirms
	Document Link																Links docs by hypertext
	Tikit Plus Suite																Relationship management
Entreprise		**Hummingbird**															
Hummingbird BI	Hummingbird CollaborationTM																Hummingbird Enterprise(TM) offers customers a 360 degree view of their knowledge assets by bringing together Hummingbird's industry leading portal,connectivity, document management, records management, knowledge management business intelligence, collaboration, and data integration solutions into an integrated enterprise information management system (EIMS). It offers everything organizations need to manage the entire lifecycle.
	Hummingbird DM																
	Hummingbird ETL																

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	Hummingbird KM™																
	Hummingbird Portal																
	Hummingbird RM																
	Hummingbird SearchServer																Document summarization, Natural Language Processing, Dynamic Clustering, etc.
Entreprise		**ServiceWare**															
	Knowledge Portal																Leading provider of web-based knowledge management solutions for customer service and support.
	ServiceWare Enterprise																Personalization of knowledge by user.
	Cognitive Processor																It creates a network of concepts that are associated based on experience.
	SmartMiner																It captures and learns from external documents.
Entreprise		**Autonomy**															
User Interfaces	Portal-in-a-Box™																
	Active Windows Extensions (AWE)																links users with relevant information they require
	Active Knowledge™																APPOL (Applications Operating Layer) - automatically brings relevant information to employees as they work.
	Retrieval																It allows content to be searched in any language and any format, wherever it is stored
	Visualization																displays the innumerable correlations that exists between the interactions of users and the information they process in a single field of view
	VeryLite™																APPOL (Applications Operating Layer) - interface to Autonomy's technology that provides functional compatibility with manual legacy systems
	Document Management																Allows a computer to go beyond keywords and metadata to identify concepts within the text itself to determine which are the most important and to automate the processing of this content, regardless of its format, location, language, application it's been created with or stored in.
	Collaboration & Expertise Networks - CEN																Communities of Practice
	Universal Repository Interfacing																Autonomy handles all types of information and provides a range of highly scalable components that automatically aggregate more than 200 different content formats

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Autonomy Product Orientated Drop-in Solutions (PODS) & Portlets	BEA Weblogic Portal																PODS, enable organizations to automatically add value to their existing IT investments. By effortlessly embedding IDOL Server functionality such as Automatic Personalization, Collaboration, Categorization into the epicentre of third party applications
	SoftSound																delivers audio processing applications to enable live or recorded speech to be manipulated, edited, searched and hyperlinked as easily as text.
Entreprise		**Tenfold**															
Universal Application																	software development platform that reduces the time and cost of complex applications development
Entreprise		**SAP**															
mySAP Business Suite	mySAP Business Intelligence																provides data warehousing functionality, business intelligence tools, best-practice models, business analytics, and administrative resources.
	mySAP Enterprise Portal																provides you with a unified view that spans SAP and non-SAP applications, data warehouses, desktop documents, internal and external Web content, and collaboration tools
SAP Industry Solution Portfolios	SAP for Higher Education & Research																**Knowledge Management:** Web check-in, authoring, and editing, Performance assessment workbench, Integration with document management
Entreprise		**Hyperwave**															
eKnowledge Infrastructure	eKnowledge Suite																It enables users to contribute, modify and access information utilising a comprehensive range of document and content management functions, for the set up and rapid deployment of intranet and extranet sites.
	eKnowledge Portal																
	eLearning Suite																It combines the benefits of traditional classroom settings with the advantages of web and computer-based training. Virtual classroom
	eConferncing Suite																Featured conferencing environment, ability to store sessions within the knowledge repository, thus generating accessible knowledge for the whole enterprise
eKnowledge Suite Extensions	Team Workspace																It facilitates collaboration amongst geographically separated individuals, helps to create communities of interest, and builds an archive of knowledge gathered in project teams across the extended enterprise.
	Workflow Option																It introduces Business Process Management to our solutions and applications. Enables to create and manage process definitions, initiate business cases and to work on tasks in an easy and intuitive way. It allows you to model all important, formal activities in the company into processes that ensure that all communication and documentation work is done in a well-defined way and that quality standards are also met if time gets inherently short.
	Web Content Option																It facilitates producing Internet, Intranet and Extranet pages easily.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Hyperwave IS/6		■						■									server software application that underpins all the Hyperwave Smart Solutions.
Hyperwave Virtual Folders																	A tool designed to make the process of handling documents on Hyperwave as simple as possible.
Software Development Kit																	Application Programming Interface (API) based on current programming languages. SDK accelerates development and enables programmers to rapidly build scalable solutions.
Entreprise		**SER**															
	SERbrainware™				■												It can recognize, classify, extract, share, and store useable knowledge from volumes of information with remarkable speed and accuracy.
	SERglobalBrain™							■									It goes beyond traditional search and retrieval solutions and understands the meaning, content and context of information, regardless of file format or source.
	SERsynergy™	■															It creates a centralized knowledge repository for your organization by bringing together the disparate elements of your operational environment. It provides a flexible, total solution for all of your information capture, storage, and retrieval needs.
	SERdistiller™				■												It classifies the full range of document types from completely unstructured to fully structured documents.
	SERprocess™											■					Automation, collaboration and management of routine business processes. SERprocess is able to interpret the process definition, interact with the workflow participants, manage activity time, send alarms, and interoperate with external systems.
	SER eDM™	■															Knowledge-enabled document management system that is capable of organizing a diverse range of documents regardless of format.
Entreprise		**MDY**															
	FileSurf™	■															Manages all information regardless of whether the information is in emails, electronic or physical files.
Entreprise		**PRIMUS**															
eServer Knowledge base	Quick Resolve															■	Guides first-level service agents through a rapid problem resolution process.
	iView	■															It's a catalyst for your organization to more effectively access, analyze, and improve existing enterprise information.
	eSupport					■											Enables customer service and support organizations to publish knowledge — real solutions to real problems — for direct customer access via the web.
Answer Engine		■															delivers quick, relevant answers to plain-English questions by bringing widespread corporate knowledge to support agents, as well as to customers, partners, and employees via the web
Entreprise		**APPIAN**															
	Appian Collaboration		■														It is a web-based application that gives your employees a customizable workspace, called a Knowledge Center, for developing knowledge assets, while facilitating information control and reuse.
	Appian Portal					■											It is a web-based desktop that provides users with a single point of personalized access to enterprise applications, information, and data sources from within and outside the organization.
	Appian Personalization		■														Providing a secure, scalable, web-based environment to manage preferences, attributes, and relationships between individuals and their communities, Appian Personalization is the most advanced engine for delivering personalized collaboration to the enterprise.
	AppianWorkflow											■					An integrated, Web-based solution designed to automate and deploy business processes across an enterprise. automates repetitive tasks and transactions to reduce process cycle times, accelerate exception handling, implement best practices, and optimize resource allocation through real-time monitoring of business workloads and personnel across functional, organizational, and geographical boundaries.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Entreprise		**NEXIDIA**															
	NEXminer																It provides extensive audio-video intelligent mining (AVIM) capabilities such as audio-video contents analysis, archiving, searching, monitoring, notification, and intelligent mining.
Entreprise		**Staffware**															
Staffware Process Suite																	The 6 layer, 11 component suite provides a complete offering for BPM solutions. The SPS is a unique Process Management framework, which enables customers to pick-'n'-mix the components they need to automate their process requirements without having to purchase products from different vendors.
Entreprise		**Autodesk**															
	Autodesk Streamline																An easy-to-use hosted project environment that helps you share design and project data securely, collaborate more effectively, and improve business processes throughout your product lifecycle.
	Buzzsaw™.																It helps keep your project teams connected and on the same page. These powerful services help you achieve more team productivity, profitability, and project control throughout the project lifecycle.
Entreprise		**Kinematik**															
	eNovator																Helps capturing the research knowledge as it is generated in the laboratory without imposing extra overhead on the researcher. eNovator then links this knowledge with the results generated as well as with the operational and strategic management processes. The eNovator application sits on the best of breed Knowledge Management **platform LivelinkTM** from OpenText. Livelink is a 100% web-based enterprise knowledge management system which incorporates features such as a sophisticated search tool, document version control and auditing, collaborative workspaces and nine levels of security.
Entreprise		**Newgen**															
	OmniDocs																It allows you to maintain a common repository of scanned and electronic documents.
	OmniReports																A solution through which you can Archive, Work on, Share, and Distribute various computer generated reports in your organization. Possibiolité de faire des annotations.
	eWorkstyle																It is a system that integrates document management, workflow, and a virtual office. You can e-enable all your business processes, effectively share all your documents, and manage your time.
	OmniExtract																Data Capturing solution lets you extract business-critical information from Forms for further use in external Database Application, Document Management, Workflow, Business Process Management, Content Management and other Information Management Systems.
	OmniKit																Power-packed and versatile collection of more than two hundred indispensable functions specifically compiled for high-end development of Image Processing and Document Management Solutions. Available in the form of DLL-based SDKs, these libraries provide extensive image handling tools.
	JPack																Java based counterpart of our renowned, Windows-based OmniKit, for extensive and effective Rapid Application Development for Document Management solutions.
Entreprise		**80-20**															
	80-20 Document Manager																enterprise scale document management system to help manage all types of content – email and email attachments, documents, Web pages, XML files, rich media, etc.
80 - 20 One Search	Discovery																It has the ability to handle both key word queries and general **concept-based queries**. Using a combination of advanced natural language processing, concept based classification and neural networks technology, Discovery extracts concepts in a query, relates them to concepts in stored documents, and then returns an accurate list of automatically categorized results, making it easy for users to locate the exact piece of information searched for. not restricted by language and can be applied to non-text data such as voice, music, image and film.
	Meta Search																It consolidates and categorizes search results from both internal and external sources. compiling results in a sensible, comprehensive list.
	Retriever Enterprise																A search tool that executes fast, accurate searching of all **email** folders and local/network file systems, to give users one access point to information stored on their personal systems.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Entreprise		**infostrength**															
Smart Enterprise Suite (SES)	Project Management Center																A web based modular and configurable, collaborative application that allows employees, customers and partners to share information while it protects and centralizes your intellectual property.
	Document Management Center																The Document Management Center focuses on Quality and other critical documents to the organization, including the SOPs.
Entreprise		**Anacubis**															
	anacubis™ Desktop																Designed to support information professionals in a number of markets, the anacubis™ Desktop can draw content from anacubis-enabled business information providers. Individual users can drag and drop information from any and all of these resources, as well as their own information, into the anacubis™ Desktop. The product instantly reconciles all the information to create one consolidated view of the subject matter, with an easy-to-navigate map of relevant and interrelated points of information to deliver instant analysis and insight.
Entreprise		**AskMe**															
	AskMe Enterprise																enables corporations to efficiently create and manage Employee Knowledge Networks by providing the most comprehensive functionality in a single solution, which consists of three distinct areas: Knowledge Exchange Services, Processes Automation Engines, and Integration Modules
Entreprise		**CA**															
CleverPath Portal & Business Intelligence	CleverPath Portal																It integrates information into a personalized, intelligent and engaging environment that can be accessed from a web browser, mobile phone or wireless PDA.
	CleverPath Collaboration Option																Currently in BETA status. enables the exchange of information, ideas, data and knowledge among employees, partners, customers and suppliers. User awareness, instant messaging, chat, web-based audio/video conferencing and co-browsing integrated with CleverPath Portal enable multi-party ad hoc and scheduled secure collaboration.
	CleverPath Advanced Access Control Option																Currently in BETA Status. provides safe, secure access to internal and external websites, applications and content delivered via CleverPath Portal. With single sign-on for all CleverPath Portal content, this option simplifies access for authorized users, prevents unauthorized access, halts intrusions, enforces security policy, reduces administrative costs and aids implementation of new web-based business processes and services.
	CleverPath Reporter																It enables both novice and expert users to easily create and automatically distribute customized reports. This high-performance reporting solution will help your organization draw on data from a diverse set of distributed databases and platforms for a complete, accurate view of critical information.
	CleverPath Forest & Trees																It simplifies development of intuitive, business-intelligence applications that help your organization proactively identify trends, risks and opportunities through a customized, visual presentation of critical information.
	CleverPath OLAP																It provides multi-dimensional analysis of large volumes of data, delivering valuable information quickly. With CleverPath OLAP, users can track and analyze key performance indicators, discover correlations between a broad-range of variables and create insightful analyses that help improve business processes.
	CleverPath Aion Business Rules Expert (BRE)																It enables an organization to effectively manage and automate complex processes though intelligent applications. By utilizing the knowledge and expertise encapsulated in business rules that can be shared across the organization, CleverPath Aion BRE facilitates consistent policy enforcement and enhanced decision-making at all levels.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	CleverPath Predictive Analysis Server														■		Industries can deploy intelligent applications to monitor and track unusual market conditions or business patterns. Provides insights into customer preferences based on customer history, demographics data, and other available customer information.
Entreprise		**Inxight**															
	Inxight SmartDiscovery												■				It automatically classifies and analyzes unstructured text data - in 26 global business languages - and presents it in an intuitive visual and text-based browsing environment. This allows users to quickly find and retrieve the precise, relevant information
	Inxight VizServer													■			A method for visualizing and exploring large information collections. VizServer creates graphical data visualizations, enabling users to easily explore and quickly find what they are looking for. VizServer is effortlessly deployed throughout an enterprise and quickly accessed from a Web browser.
	Inxight Categorizer	■															It classifies documents for fast, accurate delivery. Categorizer is highly scalable and can manage thousands of categories and millions of documents.
OEM Software	Inxight's LinguistX® Platform														■		It provides advanced text analysis capabilities in 26 languages, making it the solution of choice for search engines, data mining applications, indexing applications, and text categorization and routing tools.
	Star Tree™ SDK													■			APIs for programming in either Java or ActiveX environments. for navigating and visualizing large hierarchies of information. In a study at Xerox PARC, this technology was shown to be 62% better for navigation than the standard Windows tree control, which itself is more effective than typical page-after-page Web user interfaces.
	Inxight Summarizer™ SDK														■		It can summarize a typical document in a fraction of a second. utilizes consistent sentence-selection criteria that match the conceptual content of documents.
	Table Lens™ SDK								■								It enables programmers to rapidly integrate a patented visual data analysis technique into their software applications and Web sites.
	Inxight ThingFinder™ SDK												■				It provides advanced text analysis technology that automatically identifies and extracts key entities such as people, dates, places, companies, or other "things" from any text data source, in multiple languages. one of the most powerful text analysis and categorization tools on the market.
Entreprise		**IBM**															
IBM Lotus software	IBM Lotus Team Workplace		■														Web-based solution for creating team workspaces.
	Domino Document Manager	■															organize, manage, access and share documents
	Lotus Discovery Server													■			It extracts, analyzes and categorizes structured and unstructured information to reveal the relationships between the content, people, topics and user activity in an organization. It will automatically generate and maintain a Knowledge Map (K-map) to display relevant content categories and their appropriate hierarchical mapping that can easily be searched or browsed by users.
	Lotus(R) Extended Search												■				It searches in parallel across many content and data sources, returning integrated query results into a Web application
	Lotus Workflow											■					It offers an easy-to-use tool to design and adapt business processes and track work as it moves through your organization.
	Lotus Web Content Management Solution				■												It enables you to rapidly deploy content and existing Domino assets in a dynamic and customized web environment.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	IBM® DB2® Content Manager																A single, open, and comprehensive platform for managing, sharing, reusing, and archiving of all types of digitized content.
DB2 Intelligent Miner	DB2 Intelligent Miner Visualization																It provides data mining model-analysis via a Java-based results browser. DB2 Intelligent Miner Visualization allows experts and non-experts to view and evaluate the results of the data-mining modelling-process.
	DB2® Information Integrator for Content																It provides broad information integration and access (structured and unstructured information)
Entreprise		**Xythos**															
	Xythos WebFile Server																delivers advanced file and content management functionality without changing the way users access and store unstructured file information
	Xythos WebFile Client																Secure file access and sharing. version control, file locking and advanced permission control
Entreprise		**Kofax**															
Ascent	Ascent Capture																Information capture application. collecting paper documents, forms and e-documents, transforming them into accurate, retrievable information, and delivering it all into your business applications and databases.
Mohomine	mohoClassifier v2.3																automated solution to content categorization
Entreprise		**Plumtree**															
Enterprise Web Suite	Plumtree Corporate Portal																It assembles the applications and workspaces in the Enterprise Web, indexes and organizes content, and rationalizes security and user information. the knowledge directory is an enterprise-wide taxonomy for organizing content from Web sites, document databases and file systems, as well as portlets, communities and user profiles.
	Plumtree Search Server																It indexes all the resources in the Enterprise Web.
	Plumtree Collaboration Server																It lets people across the Enterprise Web work together on projects—setting schedules, assigning tasks, sharing documents and exchanging ideas. It supports project templates, which allow project leaders to quickly launch new workspaces in the portal or reuse successful projects as templates for future workspaces. a searchable set of threaded conversations
	Knowledge Directory																Enterprise Web's knowledge management system. organizes access to all the electronic resources created within the Enterprise Web, as well as content and services integrated from other systems.
	Personalized Pages																A space for portal users to assemble the electronic information and tools relevant to their work.
	Plumtree Content Server																It manages and publishes content in portal applications and across the Enterprise Web. For intranet, extranet and Internet sites. Information published to all of these sites can be accessed in a single search, and pages from across these sites can be linked together to create a cohesive user experience.
Plumtree Integration Products	Plumtree Portlets																Portlets are Enterprise Web components operating on separate computers that users can interact with directly via the portal.
	Crawler Web Services																Indexes documents and Web pages in the Enterprise Web, surfacing the content in the portal's Knowledge Directory.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	Federated Search and Search Web Services																It allows Plumtree to issue search requests to a wide variety of search engines running on any platform, anywhere on the Internet, and then consolidate the results into a single results page.
Entreprise		**Agilence**															
Content-centric Information Management Product	REALTIME™ Search Engine																It allows you to quickly find information in Microsoft Office and Adobe pdf-documents, while supporting advanced search. The final product will be released in Q1 2004.
	REALTIME™ Interactive Manuals																semantically connected annotations of manuals by enriching the formal content with tips, tricks and insights from the field
	XPEERION Expert(ise) Location & Management																People-centric Information Management Products. Benefit from the full power of XML-based semantic-web for effectively managing information and knowledge flows and - most important - for making the interactions simply smarter for your users: From the smart categorization of questions to the smart social pattern-matching between questions and experts, up to the smart retrieval of existing answers to similar questions - for maximum speed and productivity.
	SHARENET™ Collaboration Workspace: Team Rooms																closed environments provide all the services that teams and communities need for their day-to-day operations: Services for team coordination, communication and a team file service with document-management functionalities like versioning and check-in/check-out
	Project Lifecycle Management																Process-centric Information Management Products. It provides the sound basis for professional project portfolio management: Starting with the approval of new project activities, followed by their distributed reporting and controlling over the web up to the structured capturing of key learnings, consistent project documentation and archiving
	Enterprise-Productivity Suite (EPS)																Effective collaboration and information sharing along business processes. User Directory & Yellow Pages, Team Rooms, Instant Messenger, Discussion Forums, Configurable Project Portals, Configurable Community Portals, Community Expert-Location System, Information-Management Services...
	XPEERION																Smart XQuery Information-Integration Server that supports application development 100% in XML - from the high-speed searchable XML-database over the integration and application logics all the way up to the presentation logics. Semantic - Web: we can support you with simple, XML-schema-like semantics or as well substantially enhance the richness of representation of your XML with a DARPA Agent Markup Language (DAML) or Ontology-Interchange Language (OIL) - like ontologies.
Entreprise		**NOVO**															
	KB-Personal																Web Based, Short & Long Content Titles, Drill Down Navigation, FAQs, Search, WYSIWYG HTML Editor, Attachments, etc.
	KB-Gold																KB-Personal + Unlimited topics and sub-topics, Publishing Status and Basic Access Levels, Article Email Ability, Unanswered Question Submission
	KB-Platinum																KB-Gold + Permission Management, Rating System, Document Routing and Approval for Document Management, Automatic Document Archiving and Version Control, Question Management, Statistical Reporting, User Roles management, Thesaurus Engine
Entreprise		**Traction**															

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
Traction Software's Enterprise Weblog	Traction® Instant Publisher™																It serves to capture and publish articles into the system. A desktop extension with a point and click interface to post selections from Microsoft Word, Outlook, or Internet Explorer as articles in the Traction system.
	Newspage																It presents articles in various levels of brevity from Headline with a full paragraph to a ticker listing the title of all new entries
	ExecutiveSummary™																An automated, scheduled newsletter, summarizing new entries, organized by permissioned project, and pushed through email. Users quickly scan the newsletter and click into Traction if an entry looks interesting or needs response.
	Traction® Communicator™																A simple, low cost platform for disseminating information and collecting and acting on comments and responses. Communicator offers an easily updated interactive newspage, complemented with an automated summary email.
	TeamPage™																working communication and information capture within and between teams
Entreprise		**Longview**															
	LRALTM																Role-based Applied Learning application, LRAL, provides a common set of learning and knowledge management tools which connect the organization's finance community.
Entreprise		Entopia															
Quantum Suite	Quantum Collect																It captures unstructured information from any digital source, including the Web, e-mail, Microsoft® Word, PowerPoint, Excel, and Adobe® PDF files. It identifies key concepts, then pairs these key concepts with contextual information, are stored as metadata in the form of a dynamic semantic profile. It provides an automatic summary and suggests the best classification of the information.
	Quantum Collaborate																A working repository of information and ensures that the information is always available. By enabling information sharing and collaboration through shared folders, threaded discussions and e-mail, Quantum Collaborate enables enterprise users to efficiently distribute the kind of information needed to solve problems and make decisions.
	Quantum Capitalize																It locates relevant information. It has the ability to summarize a collection of documents into a visual representation called a K-Map. It allows knowledge workers to select a folder, or the results of a search query, and display a graphical, semantic network representation of the relationships between concepts contained in the selected documents.
Entopia K-Bus - Enterprise Knowledge Infrastructure	Entopia K-Bus Knowledge Locator																A search engine that simultaneously locates content and experts across disconnected information repositories in an enterprise. It locates relevant documents based on their semantic content, on user activity surrounding such content, and on expertise related to the query.
	Entopia Enterprise Social Network Analysis																It identifies topic-based networks created by community leaders, subject matter experts and peers. The results are displayed as a map showing community leaders, subject matter experts, peers and sets of linked and disjointed communities.
	Entopia K-Force - Knowledge-enabled CRM																Knowledge-enable the marketing, sales and customer care teams while leveraging your Salesforce.com investment. These solutions are built on top of the Entopia K-Bus enterprise knowledge infrastructure, a unified virtual metadata repository that connects end-users to information, people and resources across the enterprise.
Entopia Knowledge Builder	Taxonomy Discovery and Classification Software																It provides a fast and seamless way to organize existing information assets into the Entopia Quantum™ knowledge base. Develop custom taxonomies based on your existing enterprise content. Maintain the integrity of your taxonomy structure using the Entopia's Quantum Smart Classification feature.
Entreprise		**Eskadenia**															

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	ESKADENIA®CMS																Tool to create websites and to manage, edit and publish website content.
	ESKADENIA® Workflow																Automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal.
Entreprise		**Interzen**															
	InterZen Content Manager (IZCM)																It allows managing Internet, intranet and extranet sites with database sourced content.
	Knowledge-sharing and document management																
Entreprise		**Convera**															
	RetrievalWare																Index, search, categorize and link information across an enormous range of distributed sources. can search for concepts or units of meaning instead of merely simple terms and exact word matches. highlighted search results showing matches to both the exact query terms as well as semantically expanded terms and concepts that are related to the search topic.
Entreprise		**ePeople**															
ePeople Teamwork 5.0™	Solution Center																It creates a workspace for each customer issue, providing a place where every member of the team can get a common and persistent view of the issue, and communicate and share information.
	Knowledge Builder																When support analysts first enter a customer issue, they immediately have access to time-saving information captured from similar issues that have previously been resolved.
	Expertise Manager																Who knows what. It scours user profiles to locate the best people to help resolve an issue. provides a list of recommended advisors from both inside and outside your company based on the profiles maintained for each person, and ranked based on how these people have been used to resolve similar issues in the past.
	Reporting & Analytics																It provides the tools needed to continuously measure, optimize, and improve all aspects of knowledge capture and reuse, expertise sharing and issue resolution.
	Resolution Engine																managing the supply side of the support process
Entreprise		**OpenPages**															
OpenPages Server (OP4)	CONTENTWARE 3.2																content production solution that satisfies your newsroom and media convergence requirements by supporting the entire content lifecycle - creation, management and deployment
	SARBANES-OXLEY EXPRESS																Internal Controls Management System (Finances), supporting: Project Management, Controls Documentation, Collaborative Task Management, Issues Management, Reporting and Monitoring, COSO-based Process and Controls Repository, Leading Audit Firm Methodology and Best Practices Support.
Entreprise		**KVS**															
	Enterprise Vault for Exchange																It stores electronic mail messages in such a way that they can be recovered as usable messages exactly as they were before being moved from Exchange, with all their properties and attachments intact.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	Enterprise Vault Compliance Accelerator														■		Proactive monitoring of the content of e-mail communication between individuals and groups can be implemented without huge administration and manual overheads.
	Enterprise Vault Discovery Accelerator												■				Providing a high-level of organization and structure to your email system, Enterprise Vault Discovery Accelerator enables information to be quickly tracked, reviewed and marked. Relevant information can be easily qualified and rapidly brought to the surface.
	Enterprise Vault for Sharepoint	■															Enterprise Vault archives and offloads older data to keep the SharePoint Portal Server store lean and focused on newer, most frequently accessed items.
Entreprise	**EEDO**																
	ForceTen										■						It enables you to provide employees, partners and customers with push and pull access to knowledge via e-learning, on-the-job support, a searchable knowledgebase and knowledge sharing. Content Authoring, Document Management, Knowledge Sharing.
	ForceTen Simulator										■						It enables rapid development of simulation-based training for software applications and forms-based processes. allows you to quickly replicate the software interface, then create scenarios representing the various tasks associated with effectively using the software.
	Webclass										■						Web-based, real-time conference and collaboration software tool that provides an effective way to deliver electronic presentations as well as interact with an audience of remote participants. you can extend a view of your desktop, including documents and applications, to anyone, located anywhere, anytime…using only a Web browser.
Entreprise	**KAMOON**																
	Connect Actions™		■														It lets organizations build "virtual communities" around projects, meeting agendas or any other business activity to better manage execution across organizational boundaries.
	Connect Experts™		■														solution for expertise profiling and expert location
	Connect Enterprise™		■														Managed Q&A, Re-Use, leveraging the Kamoon Connect Previously Asked Questions knowledge base, Reporting to monitor solution usage, identify knowledge gaps, and discover emerging knowledge
	Connect Mail™		■														offering expertise profiling, expert location and managed Q&A through a simple, yet powerful email interface
	CONNECT FOR LOTUS		■														to introduce expertise location and management into an organization with a product that seamlessly integrates into Lotus Notes
	Connect Application Builder™		■														Provides the flexibility to modify and extend the Connect Enterprise or Connect Experts solutions
Entreprise	**ISYS**																
	ISYS:desktop												■				Find information fast in reports, emails, databases, attachments and more, on your desktop or across a network. For a comprehensive search from your desktop.
	ISYS:web												■				Find and share information across an intranet or website. Includes web server functionality for use in a shared, web-based environment.
	ISYS:web.asp												■				Embed a fully featured search engine into a Microsoft IIS intranet or website.
	ISYS:sdk												■				Embed a fully featured search engine into a portal, website or custom application.
	ISYS:spider												■				Find information fast in external websites.
	ISYS:rdu						■										Manage shared or remote ISYS search installations.
	ISYS:publisher														■		Publish and distribute information to CD, floppy disk or a network with full search functionality.
	ISYS:intradisk														■		Publish HTML pages to CD with full built-in ISYS search capability.
	ISYS:image	■															Transform paper-based information into accurate, searchable data.

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	ISYS:hindsite																Find information in previously accessed websites
Entreprise	**KMtechnologies**																
	Work2gether																Web-based Collaboration software and Document Management software that enables organizations to create, store, publish and process documents, forms, content and tasks... simply and securely.
Entreprise	**MUSE**																
	MuseSearch																Unlimited numbers and types of information sources can be searched simultaneously with a single user query. Results are of the highest quality because searches are translated into each source's own native language and protocol
	MuseWire																Automated information alert service. Users receive personalized content updates daily or on demand, based on the topics, format, and delivery medium they request.
	Expanded WorkRoom																Saved searches can be automatically re-executed on a timer, with expanded results sets (e.g., citations to full text).Saved searches can include in-search processing (de-duplication, sort limit, rank) or post-search processing specifications.
Entreprise	**New Idea Engineering**																
	Search Tuning																It works with your search technology and your web experts to identify the right page for your most important search terms, and then lets you direct visitors directly to that page.
	Search Tracking																It is the tool you need to understand what your visitors' behaviour is telling you. most popular search terms, documents viewed as a result of queries, etc.
	XPump																Content mining and data manipulation language. content can be extracted, manipulated and transformed into more flexible data formats. XPump lets us create the data properly from the start, helping ensure a successful implementation. XPump allows you to extract data and formatting information from your PDF documents so you can actually use the information you captured for easy viewing.
	DPump Developer Kit																For customers with very specific and special needs, we provide access to our underlying processor kernel through our developer API. Based on XML and Java standards
Entreprise	**Northern Light**																
	Northern Light Enterprise Search Engine																can search databases of up to 25 million documents with a single software installation on a single server. unique seventeen-factor approach to relevance ranking that considers statistical text measures, hyperlink analysis, subject classification, and date. proprietary technology that classifies every document in the database by subject, type, language, and source. We provide a complete 17,000-node subject taxonomy developed by our expert gang of librarians that is extensible and customizable. Our classification powers advanced search forms, vertical search applications, and our patented Custom Search Folders™ for results navigation.
	Northern Light Custom Search Services																Vertical Search Engines, Custom Content Integration Services, Custom Search Portals
	Northern Light Technology Licensing																Classification/Taxonomy (classifies all content along multiple dimensions, like subject, type, source, language, and region.), Crawler.
Entreprise	**Stellent**																
	Stellent Universal Content Management																integrated architecture supporting all five content management elements: Web content management, document management, collaboration management, records management, and digital asset management. Stellent's conversion options allow every content contributor to automatically publish content to your corporate Web sites or portals using familiar, native desktop applications.
Entreprise	**Stratify**																

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	Stratify Discovery System™																It organizes, classifies, and leverages a wide variety of unstructured information within a customized taxonomies. combines superior technology with human control to create a taxonomy of topics relevant to an enterprise, classify internal and external information into this taxonomy, and proactively present this information to users and business applications.
	Stratify Classification Server™																It allows software developers and service providers to embed unstructured data management technology into their products. uses multiple independent classifiers that reinforce each other and provide fine-grained, accurate results. Each classifier evaluates the document, and Stratify's patent-pending combiner technology compares their results to produce the best possible classification.
	Stratify Taxonomy Adapter for Documentum																Information management solution that seamlessly integrates Stratify's leading taxonomy and categorization technology with Documentum's award-winning, content management system. allows Documentum users to universally and rapidly access information through multiple views based on any desired attribute
	Stratify Search Adapter for Verity® Ultraseek																Search solution that seamlessly integrates Stratify's leading categorization technology with Verity Ultraseek's full-text search. automatically organizes your content into a taxonomy for easy information access. Using familiar point-and-click navigation, users can "drill down" through topics to locate documents of interest.
	Stratify Portal Adapters																Software products that bring the comprehensive taxonomy and categorization capabilities of the Stratify Discovery System to enterprise portal environments. allow inter-portlet or -gadget communication enabling documents or selected information to be classified in real time so that users can view related topics and associated documents
Entreprise		The Brain															
	BrainEKP (Enterprise Knowledge Platform)																integrates information from document repositories, Web sites, databases, and other applications. BrainEKP's knowledge architecture models the way information is created and accessed, forming a single knowledge map that reflects the best thinking of your organization. Four Key Components: universal data access, integrated collaboration, knowledge model (sets out a consistent template for how types of information are related and how they flow through the system, driving the creation of new types of information and serving as references for others), visual user interface (represents information as words called "thoughts" in a diagram that uses lines called "links" to show how everything fits together)
	Lotus Notes Knowledge Connector																Create dynamic connections and linkages across Lotus Notes, Add new relationships across multiple databases, Visualize Lotus Notes information with the context of your business process, Connect Notes data to external sources such as Sequel databases, documents and Web pages
Entreprise		**IXOS**															
IXOS®-eCON Solution Suite	IXOS®-eCONtext																It enables seamless integration of documents from any source into your key business applications. documents can be retrieved from any authorized desktop, in exactly the right business context, and with no delays.
	IXOS-eCONcert																It makes web-based access to documents possible and is a key building block for the implementation of portals.
	IXOS-Obtree C4																It enables easy creation of web content, fast integration of existing information and dynamic delivery of personalized content. The core of the offering is Obtree C4, a powerful authoring and content delivery tool, and Obtree Power Suite, a tool for indexing and categorizing information and implementing personalized distribution.
	IXOS-eCONprocess																process management technology (workflow) to create flexible and fully customized Business Process Management solutions
	IXOS-eCONserver																It is the foundation upon which all of the other IXOS solutions are built. stores and manages documents and data
Entreprise		**Concluent Technologies**															

Generic name	Tools	DM	Col	Pro	CM	CA	DR	KA	DIT	LI	EL	BPM	SE	GV	AU	TB	Description
	ConfluentIQ																It improves your decision making capabilities by uncovering knowledge. Advanced Graphical Navigation Tools. Query, compare, rollup and re-categorize data from multiple sourcesQuery, compare, rollup and re-categorize data from multiple sources.
	ConfluentEDU																data warehousing and data mining software package for K-12 schools
Entreprise		**Generation21**															
	Generation21 Enterprise																Enterprise learning system. It combines robust LMS and LCMS functionality with our browser-based content development tool. supports both online and classroom-based learning. Most important, its patent-pending "Universal Knowledge Object" technology delivers "nuggets" of information. Deliver information to users via PDAs and other wireless devices.

Source: Corporate sites of the mentioned enterprises.

Note: The highlighted elements are the ones we have found particularly interesting given their potential utility in the research laboratories or because they present special functionalities not found in the other products.

Annex 11. The identified commercial tools for supporting research organizations

Conventions	
Abbreviation	**Meaning**
GV	Graphical Visualization
ABS	Access of bibliographic sources
PBR	Publication of bibliographic references
SBL	Search of books in libraries
Cat	Categorization of documents
Wri	Writing support
Ann	Annotation Tool
ScT	Scientific Trends
IDM	Information and Data Management (Includes LIMS and E-notebooks)
Sch	Scheduling systems
AD	Analysis of Documents
LIMS	Laboratory Information Management System

Enterprise	Tools	GV	ABS	PBR	SBL	Cat	Wri	Ann	ScT	IDM	Sch	AD	Description
Thomson ResearchSoft	RefViz	■											RefViz is an essential tool designed to help researchers evaluate references easily, plan future projects and publish their work. It analyzes large numbers of references by thematic content and presents an at-a-glance overview of the main topics discussed in the reference set (Powered by OmniViz)
OmniViz	Omniviz	■											The OmniViz® visual intelligence software provides an easy way of bringing all data together, from multiple locations and in multiple formats, and allowing it to be explored in a common visual package
Thomson ResearchSoft	EndNote		■										Used by millions in Academia, Government & Industry Researchers, Scholarly Writers, Students and Librarians to search Internet databases, organize references & images, and create bibliographies & figure lists instantly.
Thomson ResearchSoft	ProCite		■										ProCite is a powerful Windows tool for researchers, librarians, writers, and students. ProCite allows searching bibliographic databases on the Internet, organize and manage references and create bibliographies in a choice of over 600 styles.
Thomson ResearchSoft	Reference Manager		■										Reference Manager is an innovative writer's tool for Windows used to search bibliographic databases on the Internet, organize references and create effortless bibliographies in hundreds of styles. New features include: instant formatting, travelling library, link to PDF/full text and new direct exports and Internet searches.
Thomson	ISI Web of Knowledge		■										It provides access to essential information for all levels of academic, corporate, and government research. It offers a comprehensive, fully integrated platform that empowers researchers and accelerates discovery.

Enterprise	Tools	GV	ABS	PBR	SBL	Cat	Wri	Ann	ScT	IDM	Sch	AD	Description
Thomson	Web of Science®												It provides seamless access to current and retrospective multidisciplinary information from approximately 8,700 of the most prestigious, high impact research journals in the world. Web of Science also provides a unique search method, cited reference searching. With it, users can navigate forward, backward, and through the literature, searching all disciplines and time spans to uncover all the information relevant to their research. Users can also navigate to electronic full-text journal articles.
Thomson	Science Citation Index®												SCI® provides access to current and retrospective bibliographic information, author abstracts, and cited references found in 3,700 of the world's leading scholarly science and technical journals covering more than 100 disciplines. The Science Citation Index Expanded™ format, available through the Web of Science® and the online version, SciSearch®, cover more than 5,800 journals.
Thomson	Current Contents Connect												It is a multidisciplinary current awareness Web resource providing access to complete bibliographic information from over 8,000 of the world's leading scholarly journals and more than 2,000 books. Users can also search a premium collection of evaluated scholarly Web sites and access evaluated, full-text Web documents in three general resource types: preprints, funding information and research activities.
Thomson ResearchSoft	Reference Web Poster												Reference Web Poster is a collaborative tool for sharing bibliographic references with colleagues on the Internet. It allows posting databases from Reference Manager, ProCite and EndNote on the Web. Colleagues with a browser can search these databases and import references into their own reference managers.
WebClarity	BookWhere												BookWhere is a powerful software package that allows the user to search hundreds of databases via the Internet. The available databases include the Library of Congress and British Library as well as public, academic and state libraries all over the world.
ThunderStone	TEXIS												TEXIS is the only fully integrated SQL RDBMS that intelligently queries and manages databases containing natural language text, standard data types, geographic information, images, video, audio, and other payload data.
ThunderStone	Thunderstone Search Appliance												This device combines the simplicity of a hosted service with the security and performance of a local solution. Using our advanced software the Appliance can handle over 1,000 typical queries a minute, providing excellent value without adding administrative overhead.
ThunderStone	Webinator												Webinator is a Web walking and indexing package that allows a Website administrator to easily create and provide a high quality retrieval interface to collections of HTML documents. Webinator serves as an example of the type of applications that can be built around Thunderstone's Texis RDBMS and Web Script.
ThunderStone	Texis categorizer												Automatically attaches categories, subject codes, metadata, and the like, to documents or text records.
SciProof LLC	sciPROOF												Software designed to streamline the scientific writing process. Seamlessly integrated with Microsoft Office®, sciPROOF™ verifies scientific spelling and formatting. The program comes equipped with a powerful database engine that includes over 250,000 technical, scientific, medical and chemical terms from the United States National Library of Medicine (NLM) and the National Center for Biotechnology Information (NCBI). Other tools for scientific writing such as reference searching and glossaries are also included. sciPROOF improves accuracy and saves users countless hours of formatting and proofreading.
Thomson ResearchSoft	WriteNote												WriteNote is a Web-based Research and Writing Tool for Students to organize references and write papers. Students can have the tools they need to take full advantage of library subscription resources and properly cite for attribution.
Thomson ResearchSoft	IMarkup Client Tool												Web page annotation tool that allows notes and markups to be made within a Web browser to "live" Web pages. The Internet now becomes a virtual notebook. Once an annotation or markup is placed on a web page, it is stored securely on the author's PC. The next time he navigates back to that page, his annotations are automatically displayed.
Thomson	Essential Science Indicators												It enables researchers to conduct ongoing, quantitative analyses of research performance and track trends in science. Covering a multidisciplinary selection of 8,500 journals from around the world, this in-depth analytical tool offers data for ranking scientists, institutions, countries, and journals.

Enterprise	Tools	GV	ABS	PBR	SBL	Cat	Wri	Ann	ScT	IDM	Sch	AD	Description
	CyberLab												It's an electronic library that collects, organizes, warehouses, indexes and safely archives all your structured and unstructured electronic records from raw data and laboratory reports to compliance records putting the information you need to improve operations in one, convenient, easily accessible location..
Scientific Software	OpenLab												A scalable, feature-rich laboratory framework for instruments and laboratory information, OpenLAB will provide you with a strategy for integrating instrumentation, local data systems, and laboratory electronic information into a fully protected, searchable, and archivable system.
Adept Scientific	E-Notebook												It provides a smooth web-based interface designed to replace paper laboratory notebooks. E-Notebook pages contain Excel spreadsheets, Word documents, ChemDraw drawings and reactions and spectral data. E-Notebook can be searched by text, structure or reaction. E-Notebook is for Windows only.
Thermo Electron Corporation	LabManager												It is designed to be highly configurable, full featured LIMS. It is easily modelled to closely match the existing data automation needs and business practices in the modern laboratory as well as on-going dynamic needs.
Thermo Electron Corporation	Nautilus												It is a LIMS designed for the unique requirements of R&D labs. A flexible and intuitive interface graphically maps laboratory workflows to meet the needs of even the most dynamic environments. Full functionality for plate handling and manipulation can be used to track plate movement and genealogy, while standard integration functionality allows data to be easily imported without coding from a variety of analytical instruments
Thermo Electron Corporation	Watson												It is a highly specialized protocol-driven LIMS specifically designed to support DMPK/Bioanalytical studies in drug development. The system was developed with input from major pharmaceutical companies, and its success is a direct result of its ease of use and the high level of service offered to assist in implementation.
LabVantage	Sapphire™												It removes lab bottlenecks to increase research time, provides complete traceability throughout the life of each sample element, and automates experimental protocols with a high-volume technology framework. Maximizing the integration of robotics seamlessly, Sapphire™ provides complete plate management solutions for the integration of laboratory operations. It supports all documentation needs for regulatory compliance. In completely managing the life of a sample, Sapphire™ gets researchers to the finish line faster while providing complete validation at every step of the process.
LabVantage	LVL												This LIMS allows automating specific laboratory processes: Sample Management, Sample Scheduling, Integration with Instruments and Systems, Flexible Reporting, Trending/Analytical Quality Control, Standard Operating Procedures Maintenance, Auditing, Security, Simple User Interface
ChemSW	Laboratory Document Control System												It is a database application designed specifically for use in controlled environments. It allows tight version control on documents where tracking revision history is required. Laboratory Document Control System provides you with an easy mechanism for creating and publishing SOP's on your network. Using Laboratory Document Control System you can also mark the status of documents and track who has control of the documents.
AgileBio	LabCollector												LIMS built around independent modules that can interact with each other, LabCollector will manage a variety of day-to-day useful lab information. Existent modules are: Strains Module, Plasmids Module, Primers Module, Sequences Module, NetPlasmid Editor, GenBank import Module, Reagents & Chemicals, Documents Module, Samples Module, Code Bars usage
Inenco	Mikon												It is a LIMS that will: cut down the turnaround-time in the laboratory, reduce manual data entries, provide a tool for graphical analysis (trend, XY-plot, SPC, etc), automate creation and distribution of reports (paper, e-mail, etc), provide a complete audit-trail and open the way to integrated analysis- and production data.
StarLims	STARLIMS Document Management												It provides tools for capturing, storing, retrieving, parsing and sharing the complete electronic record. It offers laboratory document and scientific data management in one platform.

Enterprise	Tools	GV	ABS	PBR	SBL	Cat	Wri	Ann	ScT	IDM	Sch	AD	Description
StarLims	STARLIMS Console									■			The automatically monitors the data flow providing personalized Real Time feedback to all laboratory users. STARLIMS supports full laboratory automation in a regulatory compliant enterprise system. It includes functionalities for: Sample Login, Work Assignment, Review and Approval, Results Entry, and Reports and Queries. It is located on each user's desktop and automatically administers the laboratories workflow.
AgileBio	LabCal										■		It is a robust scheduling system that enables labs or organizations to centralize their equipment and facilities resources.
QSR	NVivo											■	It is designed for researchers who need to combine subtle coding with qualitative linking, shaping and modelling. It is a fine-detailed analyser that integrates the processes of interpretation and focused questioning.
QSR	N6 (NUD*IST)											■	It is designed for powerful management and flexible analysis of text data. It is a tool kit for code-based inquiry and searching

Source: Internet Sites of the mentioned enterprises

Note: This table does not include tools for specific scientific fields.

Annex 12. The software tools proposed by researchers for managing scientific knowledge

Activity Supported	Main Functionality	Tool	Field of application
Identification and analysis of citations	Citation analysis and navigation over the e-print literature	CiteBase[155]	arXiv. org base (physics, mathematics, non-linear science, computer science, and quantitative biology)
	Discovery of complimentary scientific literatures	ARROW-SMITH (Swanson, D.R., Smalheiser, N.R., 1997)	Biomedical research
	Identification of technology trends	STIS (López-Ortega E., et al., 2004)	IIUAM[156]
Modeling of terminology of a Documentary Corpus	Indexing platform of bibliographic records - detection of thematic emergent tendencies	Beluga (Turenne, N., Barbier, M., 2004)	General
	Mapping research topics at the micro level	TermWatch System (Ibekwe-SanJuan F., SanJuan E., 2004)	General
	Modelling, analysis, verification, validation, sharing, combination, and reuse of domain knowledge bases and ontologies	ConcepTool (Meisel, H. and Compatangelo, E., 2002)[157]	General
	Text Mining software devoted to the indexing and analysis of textual corpora	NeuroNav (Lelu, A., Aubin, S., 2001)[158]	General
Analysis of Documentary Corpus	Creation, retrieval and sharing documents and annotations	Porphyry (Bénel A., 2002)	Archaeology
	Analysis of complex files	Prospéro (Chateauraynaud, F., 2003)	Controversies sociology
	Ontology "designed to support scholars in making claims by asserting relationships between concepts"	ScholOnto (Buckingham Shum, S., et al., 1999)[159]	General
	Annotation of scholarly documents [160]	ANITA (Gardoni M., et al., 2004)	Aerospace

155 See: http://citebase.eprints.org/cgi-bin/search

156 Institute of Engineering of the National University of Mexico

157 See also: http://www.csd.abdn.ac.uk/research/IKM/ConcepTool/

158 See also: http://www.diatopie.com/Ficheneuronav.htm

159 See also: http://kmi.open.ac.uk/projects/scholonto/

160 A number of web annotation tools have been developed. A summary of these tools can be seen at: http://annotation.semanticweb.org/tools/. Tough these tools are not explicitly developed for research activities, we think they can be of interest.

Activity Supported	Main Functionality	Tool	Field of application
Support to organizational knowledge	Management of organizational scientific knowledge - management of competencies	Epistheme (Oliveira J., 2003)	Agro-meteorology
	Automatic knowledge acquisition system	Prototype developed by (Tacla, C., 2003)	Research tasks
Discussions	Facilitation of structured argumentation and discourses	Dito (Angie Voos, et al., 2004)[161]	WWW - textbased discussions
	Supports the process of peer review	D3E (Buckingham Shum, S., et al., 1999)[162]	Scholarly documents
Information repository	Information storage, organization, and access capabilities distributed NASA[163] science teams	ScienceOrganizer[164]	Astrobiology Institute
	Knowledge accumulation and dissemination	NetAcademy (Handschuh, S., et al., 1998)	General - Internet
	Management of research publications	Knowledge Sharing System (Vorakulpipat C., 2004)	Nectec[165]
Lab Books	Electronic notebooks	Architecture proposed by (Sarini et al., 2004)	Biology
	Support in the preparation, execution, analysis and dissemination of experimental work	Smart Tea[166]	Chemistry
	Lab Books	MyTea[167]	Bioinformatics
	Support to data intensive in silico experiments in biology	MyGrid[168]	Bioinformatics

[161] See also: http://zeno8.ais.fraunhofer.de/zeno/web?action=content&journal=16187&rootid=16123

[162] See also: http://d3e.sourceforge.net/

[163] National Aeronautics and Space Administration (United States)

[164] See: http://sciencedesk.arc.nasa.gov/organizer/index.html

[165] National Electronics and Computer Technology Center (Thailand)

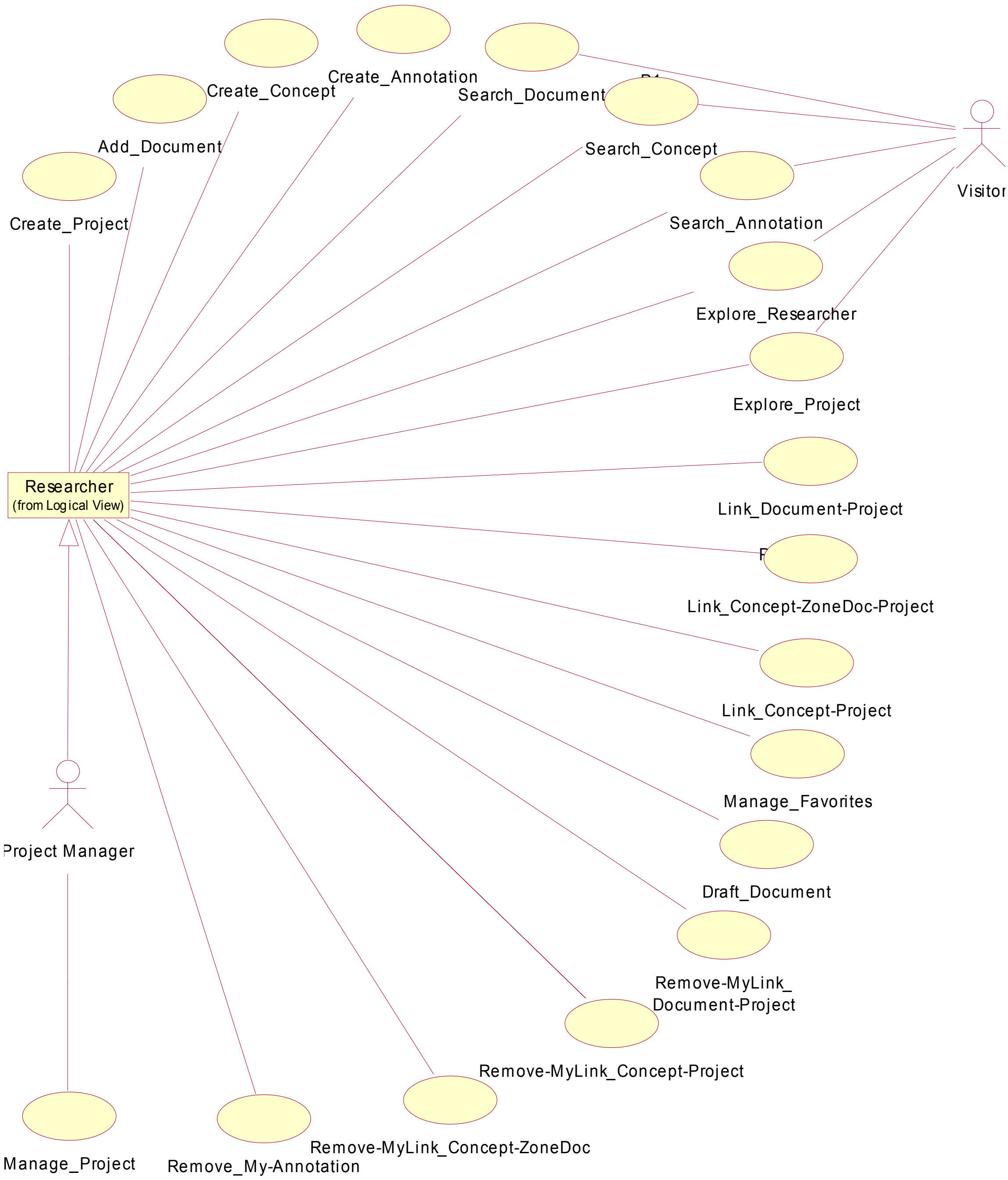
[166] See also: http://www.smarttea.org/

[167] http://www.mytea.ecs.soton.ac.uk/

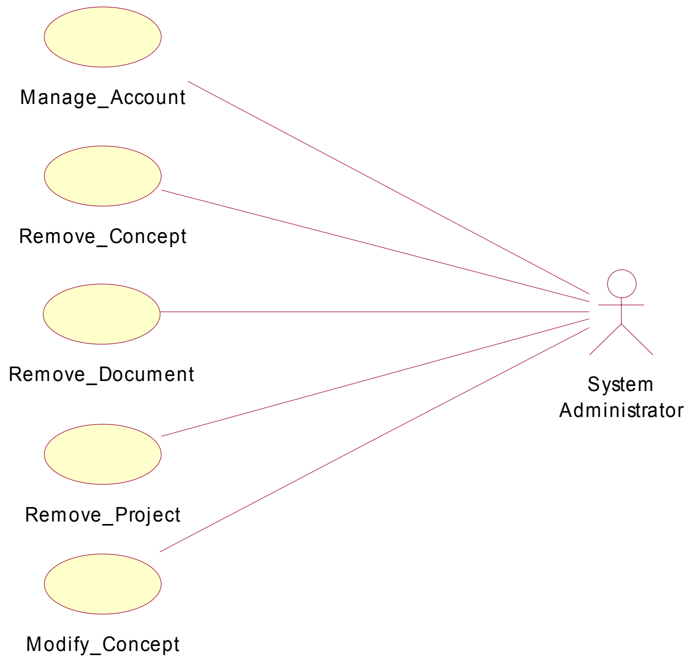
[168] http://www.mygrid.org.uk/index.php?module=pagemaster&PAGE_user_op=view_page&PAGE_id=3&MMN_position=2:2

Annex 13. Use case diagrams of the specifications of the approach

Researcher – Project Manager – Visitor:



System Administrator:



Annex 14. Interview on the researchers' practices related to the bibliographic work and the support BASIC Lab could offer to it

In order to verify the interest an approach such as BASIC Lab could have for researchers, we used two methods: 1) Installing it on a server and allowing a group of potential users to use the prototype as a support to their activities. 2) Interviewing a group of researchers to verify their practices related to bibliography and find out their opinion of BASIC Lab.

The first part consisted on a project developed to test the support that BASIC Lab could offer to a group of researchers of the GILCO laboratory when realizing their activities. This project was called "Tests BASIC Lab" and was created (on the prototype) on January 20th, 2005. The idea of this project was to test the prototype in real situations with some of the members of the laboratory, by allowing them to use it for the development of their activities. In its framework, each researcher had the possibility of creating their own projects according to their needs. Four people took part on this project: Three master's students and one PhD student. We taught these users how to use the tool as a support to perform their activities. After a 3 months period, we noticed that only two of the members of the project had used the tool. One of them, one only tested the functions and did not do any other use.

For that reason, we decided to perform a series of interviews regarding researchers' habits concerning bibliographic work and regarding BASIC Lab. The idea is to verify if BASIC Lab can help researchers perform their activities. Hence, it is important to understand the researchers' practices. The principal aspects of this series of interviews are presented hereafter.

General aspects of the interview

The interview has two parts: A directive part about the researchers' practices and a semi-directive part about BASIC Lab. Ten interviews were done with: One engineering student, three masters students, four PhD students, one temporary professor and one assistant professor. The interviews lasted around 30 minutes for the directive part (researchers' practices) and around 15 minutes for the semi-directive part (BASIC Lab). The interviews considered more important were recorded to better grasp the answers and facilitate their analysis. Six interviews were recorded: the ones made with the PhD students, the assistant professor and the temporary professor. They count for about four and a half hours of voice recordings. All the recorded interviews were transcribed in order to facilitate their analysis.

The questionnaire was composed of 29 questions. It was divided in 3 sections:

- General Aspects about the researcher and his interest in the bibliographic work (3 questions);
- The bibliographical research:
  - Information Resources (6 questions);
  - Selection of documents to read (2 questions);
  - Analysis of documents (8 questions);
  - Utilisation of documents (2 questions);
  - Filing of documents (1 question);
- Utilisation of BASIC Lab (7 questions).

After the interviews, the following stage was the analysis of the answers obtained. We will now briefly present the answers obtained about each one of these aspects.

The Researchers' Answers

We will now discuss the main conclusions concerning each one of the sections included in the interview.

• The General Aspects about the researcher and his interest in the bibliographic work

This section approached the aspects regarding the profile of the researchers. As we mentioned, we interviewed ten researchers: One engineering student, three Masters' students, four PhD students, one temporary professor and one assistant professor. The interview paid special attention to the utilisation and the management of scientific articles because, according to the literature, this is one of the main resources usually used in research activities. Thus, we noticed that all the researchers interviewed use scientific articles for their research. Most of them (seven) also use them for learning on new subjects and also to keep updated on the advances of their domains.

The interviewees' satisfaction regarding the support to the information search was divided. Six interviewees were satisfied, while the other four were not. One of the interviewees affirmed that he is never satisfied, because he has never access to all the documents identified, given the existence of diverse sites requiring paying subscriptions, unknown sites, etc. In addition, we detected a high dissatisfaction with the support to the control of references. Nonetheless, we note that almost all the interviewees were unaware of the existing tools for this purpose.

- The bibliographical research

In this section, the aspects related to the bibliographical research are treated.

  - Information Sources

According to the interview, for seven of the interviewees, scientific articles are their main source of information. Another important source of information (for seven of the interviewees) were colleagues and professors of the same area, who supplied bibliographic documents. In addition, all the researchers use search engines in their research and frequently make searches for new information.

  - Selection of documents to read

In general, the researchers have different strategies to evaluate the interest and the credibility of the identified articles before reading them. Thus, before reading a complete article, the researcher observes specific aspects of the article to decide if the document is interesting or not. These aspects are: author, abstract, headings, conclusion and references. To analyze the credibility of a document, the researchers also observe specific parts such as the highest degree achieved by the author (PhD, Master, etc), the university to which the author belongs and the bibliographical references used.

  - Analysis of documents

An important factor detected in the interview was that six of the interviewed researchers prefer articles clean, without other people's annotations before reading them. Two interviewees said that they prefer, at a first stage, clean documents to get their own ideas. If they have access to documents with other people's annotations, they like to read these people's annotations to have access to their ideas.

The great majority (nine) of the interviewed researchers prefers to read in paper. Two of them even arrived to affirm that they only read on paper. If they have an electronic version of an article, they print it and read it. Furthermore, a researcher even affirmed needing to touch and feel a document in order to read it, which is not possible on the computer.

For the annotation of documents, underlining the most important parts is a current practice. It was also observed that even when reading on a computer, some researchers make annotations on a paper notebook. Additionally, according to the interview, seven of the interviewees make an individual summary for each article.

- Utilisation of documents

To keep track of the interesting documents, six of the interviewees keep a paper copy and/or records his digital documents in a special folder according to their own classification. Some of the classification criteria mentioned are: author, utilisation objective and subject.

- Filing of documents

It was found that amongst the interviewees only one makes use of a specialised tool for the management of the references, concretely, he uses Bibtex (for Linux). Six of the interviewees do not use specialised tools for this management. They use tools such as Excel, Access and Windows Explorer (by making folders for the different categories). One of the interviewees affirmed that for the management of his files he uses Excel by classifying documents by subject. He said that it is very difficult to organize it and to bring it up to date. He loses much time in this activity. The majority (eight) of the interviewees keeps the files of their documents in personal computers. One said that he keeps his files on the Internet on his personal site, which allows him to share these files.

The next aspect addressed in the interviewed deals with the feedback of researchers regarding the potential utilisation of BASIC Lab as a support to their activities.

- BASIC Lab

This section addressed aspects related to the researchers' opinions regarding BASIC Lab. For this part of the interview, we made a demonstration of BASIC Lab to the interviewees that did not know it. Unfortunately, for these interviewees, we can only get their first reactions and not their feedback as a user. Nevertheless, four of the interviewees already knew the tool and two of them had already made use of it. The two that had already made use of the tool were the participants of the "Tests BASIC Lab" project. The other two that already knew the tool are members of GILCO laboratory to whom a general presentation had already been made. For all these interviewees the collection of data was richer, because they could supply more information according to their own experience with the tool.

In general, all the interviewees to whom the tool was shown had had excellent reactions regarding BASIC Lab. They were surprised by the functionalities of the prototype and by how it could help them. An observed fact was that the interviewees' surprise varied according to their experience. For example, the PhD students seemed more surprised and admired that the Masters' students.

All the interviewees found easy the utilisation of BASIC Lab. They also expressed the intention of using the tool. Eight of the interviewees intended to make use of BASIC Lab to assist them in their research. One of the candidates was so surprised with the tool that after the demonstration he affirmed that he would start using it. The option of searching inside annotations was seen as a great advantage by one of the interviewees; notably because this type of search is not possible in the way he currently annotates documents. He expressed is positive perception about the prototype by the following statements:

- "The tool is very interesting to explore projects and concepts from different points of view. It allows finding tracks that can be interesting or to contact people who work in a similar context."
- "Very intelligent organization of its library, gains in time, one can profit from someone else's annotations, facilitates sharing..."
- "I have never seen tools of the same type or similar."
- "Good interface and good functionalities."

Nevertheless, two other interviewees had different opinions. One of them, the assistant professor, affirmed that, at the moment, he was not motivated to use the tool because he was not doing any research this year[169]. He said that, this year, he devoted most of its time to his academic activities, for which his main source of information is books. Therefore, he did not have much opportunity to read many articles. Hence, he does not feel the necessity of a tool to manage articles. The other interviewee had a divided opinion, partly positive and partly indifferent. He affirmed that BASIC Lab is very interesting to find possible ways to follow for a research project, but it cannot help him to more efficiently organize his documents, notably for the writing of new documents, because it does not have the possibility of classifying documents according to the specific researchers' preferences. He affirmed that, in the prototype, documents can be classified according to concepts. However, he uses another way to classify documents, which is according to the objective of utilisation of the document (e.g., documents to be used for writing a chapter of his PhD dissertation or for writing an article). We note that a possibility to answer this researcher's need is the creation of sub-projects. In this way, the researcher can classify his documents according to the objective of as many sub-projects as considered necessary (which in turn can have their own sub-projects).

Amongst the modifications, that the interviewees would unanimously like to do to BASIC Lab, was the multi-criteria search and the full text search. The full text search is larger in terms of documents retrieved and is part of the researchers' habits. Conversely, the multi-criteria search allows a focalised search. Five of the interviewees would also like to control the sharing level of their files and annotations. In this way, the user could choose for example who can visualize his documents.

Other suggestions regarding BASIC Lab have also been made. One of these suggested changes was the inclusion of discussion lists about specific articles or concepts. Another suggested implementation was the creation of spaces for the development of shared understanding regarding a specific subject. In this way, a group of researchers could argue and create ideas on specific subjects. Another suggested implementation would be to allow, as mentioned above, the classification of documents according to the objectives of utilisation.

[169] We note that this person has only recently joint the laboratory and for that reason, he has not started any new research projects.

This could, for example, support the writing of new documents. In addition, one of the interviewees mentioned that he often works with mathematical formulas. However, in BASIC Lab there is not an option allowing writing mathematical formulas requiring special symbols (e.g., integral, square root, etc.). It would then be desirable to be able to create mathematical formulas in the tool.

General Conclusion of the Interview

After the realization of the interview and its analysis, we can arrive to some conclusions. Thus, the interview shown that although each person has a different way to carry out his bibliographic research, their practices also present similarities. It was also noticed that, in general, the PhD students as well as the professors are more concerned by the management of the bibliography they use. This concern can be possibly linked to the fact that their research can last several years.

In addition, the basic characteristics of the researchers' practices regarding their bibliographic research are (see 0):

- For the majority of the researchers interviewed (seven), scientific articles are their main source of information;
- Six of the interviewees only make searches if needed, while the others make searchers regularly. For two of them, this frequency is every day, for another one it is once a week and for the others it is every month.

Questions	Answers	People
You use bibliographical documents for:	To find useful information for a research project	10
	To learn on a subject of interest	7
	to keep updated on the advances in your domain	7
Are the scientific journal articles your main source of information?	Yes	7
	No	3
The documents you use are:	Obtained by yourself	10
	Supplied by the professors and people who orientates your work	6
	Supplied by colleagues	7
On the documents that you read, you prefer them:	Clean, without erasures or annotations,	6
	Clean but someone else's annotations do not bother me	3
	With other people's annotations to know their ideas	2
For the reading documents, you prefer them:	Always on paper	2
	Mainly on the computer, but also on paper	1

	Mainly on paper, but also on the computer	7
When you read a document, you:	Underline the important parts	8
	Write one general note on the text	3
	Write notes on the side of the document	5
	Make annotations on another paper	6
Do you use a tool to manage the bibliography you use?	Access	2
	Excel	2
	Paper.	3
	Windows Explorer	2
How do you keep the track of the documents you find interesting?	You keep a paper copy	6
	You keep an electronic copy on a special folder	6
After finishing a research project, what do you do with the bibliographical documents used?	You keep all the documents available on paper format	2
	You keep all the documents available on electronic format	8
	You keep everything on paper	3

Table 6. Summary of questions and answers obtained in the second part of the interview (Researchers practices related to bibliographic documents).

- The main strategies used for choosing the articles to read completely are: Reading the abstract (10), reading the heading (8) and skimming through the document (8);
- The great majority (nine) of the interviewees prefers to read documents on paper;
- Most (six) of the interviewees prefers to read clean articles, without annotations;
- Only one of the interviewees uses a tool for controlling the bibliography used.
- To keep track of the documents used, the researchers keep a digital copy in a special folder (six) and/or keep a copy in paper (six);
- The majority (eight) of the interviewees keeps (for himself) all the files (documents in electronic format) after finishing a project.

The researchers, after the presentation of BASIC Lab, confirmed its utility and evidenced their need for this kind of support. They also expressed the potential gains they could obtain by using tools of this type.

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De la gestion de la qualité à la gestion des connaissances dans les projets de recherche : Une approche par la gestion du contenu pour la recherche bibliographique

Résumé

Les activités de recherche visent la production de nouvelles connaissances. C'est pourquoi; nous nous sommes intéressés aux pratiques formelles de gestion des connaissances introduites par les organismes de recherche lors de la mise en place d'une démarche qualité. Un travail de terrain mené dans ces organismes nous a montré les difficultés pour définir des agencements soutenant la réalisation des projets de recherche, en tant que structure fondamentale pour la production de connaissances. Alors, l'analyse du déroulement des projets de recherche nous a permis de proposer une approche, montré à travers d'un prototype d'outil informatique, basée sur la capitalisation du travail bibliographique effectué par des chercheurs en contextualisant une partie des analyses des contenus effectuées à travers la définition d'un réseau d'artefacts (documents, concepts, annotations, projets, et information sur les chercheurs).

Mots-clés

Gestion de qualité, gestion des connaissances, organismes de recherche, projets de recherche, recherche bibliographique.

From Quality Management to Knowledge Management in Research Projects: An Approach through the Management of Contents in Bibliographical Research

Summary

Research activities aim the production of new knowledge. For this reason, we were interested in the formal knowledge management practices introduced by research organizations working on the implementation of a quality management system. A fieldwork carried out in these organizations showed us the difficulties to define methods supporting the realization of research projects, taken as the fundamental structure for the production of knowledge. Then, the analysis of the development of research projects enabled us to propose an approach, shown through a prototype of a software tool, based on the capitalization of the bibliographical work carried out by researchers. The approach contextualises a part of the analyses of the contents carried out by researchers through the definition of a network of artifacts (documents, concepts, annotations, projects, and information on the researchers).

Keywords

Quality management, knowledge management, research organizations, research projects, bibliographic research.